HP 651B

# 651B TEST OSCILLATOR

## OPERATING AND SERVICE MANUAL

HEWLETT hp PACKARD

HP 651B

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## CERTIFICATION

*The Hewlett-Packard Company certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. The Hewlett-Packard Company further certifies that its calibration measurements are traceable to the U.S. National Bureau of Standards to the extent allowed by the Bureau's calibration facility.*

## WARRANTY AND ASSISTANCE

All Hewlett-Packard products are warranted against defects in materials and workmanship. This warranty applies for one year from the date of delivery, or, in the case of certain major components listed in the operating manual, for the specified period. We will repair or replace products which prove to be defective during the warranty period. No other warranty is expressed or implied. We are not liable for consequential damages.

For any assistance contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided at the back of this manual.

OPERATING AND SERVICE MANUAL

(HP PART NO. 00651-90005)

# MODEL 651B
# TEST OSCILLATOR

SERIALS PREFIXED: 811-

Appendix C, Manual Backdating Changes,
adapts this manual to the following instruments:
Serial No. 647-02850 and below.


P. O. Box 301, Loveland, Colorado, 80537 U. S. A.

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## LIST OF ILLUSTRATIONS

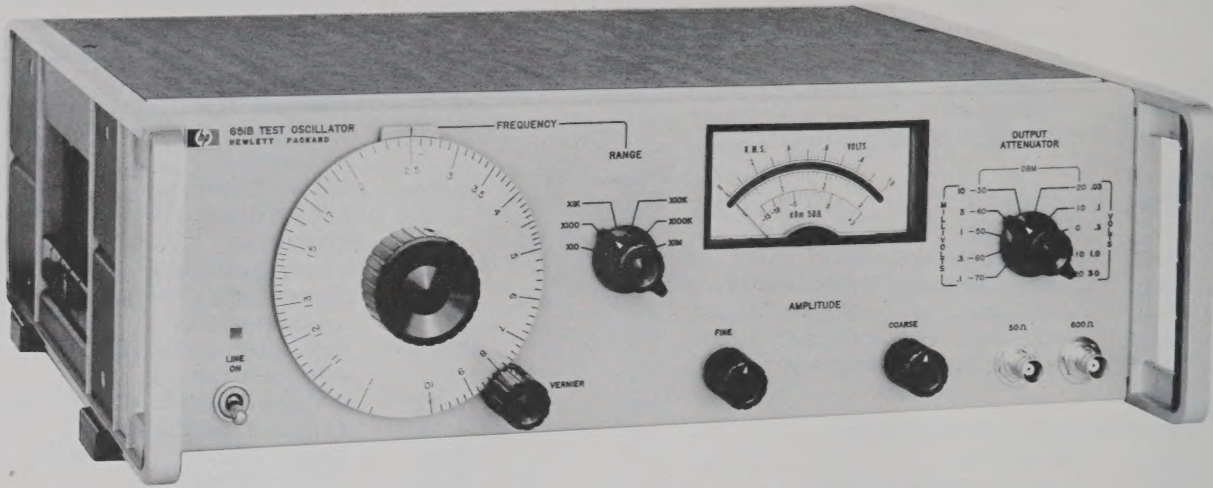



Figure 1-1. Model 651B Test Oscillator

Table 1-1. Specifications

Frequency Range: 10 Hz to 10 MHz, 6 bands, dial calibrations: 1 to 10.

Dial Accuracy: (including warm-up drift and ±10% line voltage variation).
±2%, 100 Hz to 1 MHz.
±3%, 10 Hz to 100 Hz and 1 MHz to 10 MHz.

Output:
Maximum: 3.16 V into 50 Ω or 600 Ω
6.32 V open circuit
+23 dBm into 50 Ω
Ranges: 0.1 mV to 3.16 V full scale, 10 steps in 1, 3, 10 sequence, coarse and fine adjustable. -70 dBm to +23 dBm (50 Ω output) full scale, 10 dBm per step, coarse and fine adjustable.
Flatness: (Amplitude not readjusted to a reference on the output monitor.)
±2% 100 Hz - 1 MHz
±3% 10 Hz - 1 MHz
±4% 10 Hz - 10 MHz*

* This specification applies only at 50 Ω or 75 Ω output. The response above 1 MHz at the 600 Ω output is affected by capacitive loads.

(Amplitude readjusted to a reference on the output monitor.)

| Range | Frequency 10 Hz | 20 Hz 4 MHz | 10 MHz |
|---|---|---|---|
| 3 V and 1 V | 2% | 1% | 2% |
| 0.3 V to 0.3 mV | 2.5% | 1.5% | 2.5% |
| 0.1 mV | 3% | 2% | 3% |

Distortion: less than: 1% 10 Hz to 2 MHz, 2% at 2 MHz to 5 MHz, 4% 5 MHz to 10 MHz.
Hum and noise: less than 0.05% of maximum rated output.

Output Monitor: voltmeter monitors level at input of attenuator in volts or dB. Top scale calibrated in volts. Bottom scale in dB.
Accuracy: ±2% of full scale.

Attenuator:
Range: 90 dB in 10 dB steps.
Overall accuracy: ±0.075 dB, -60 dBm to +20 dBm.
±0.2 dB, -70 dBm to -60 dBm.

Amplitude Control: 20 dB range: coarse and fine.

Amplitude Stability: ±2% per mo., 20°C - 30°C.

Temperature range: 0°C to +50°C.

Power: 115 V or 230 V ±10%, 30 W, 50 to 1000 Hz.

# SECTION I
# GENERAL INFORMATION

## 1-1. DESCRIPTION.

1-2. The Hewlett-Packard Model 651B Test Oscillator is a wide range capacitance-tuned oscillator covering a frequency range from 10 Hz to 10 MHz. The oscillator has a stable sine-wave output signal that is adjustable from 10 microvolts to 3.16 volts into 50 or 600 ohms. The Model 651B Test Oscillator is shown in Figure 1-1 and the specifications are given in Table 1-1. This manual is written for the standard Model 651B Test Oscillator; refer to paragraph 1-7 for differences between the standard instrument and Options 01 and 02.

1-3. Two output impedances are provided at front panel output connectors. The 600 ohm connector provides an output with an impedance that is compatible with transmission lines and many distribution systems. The 50 ohm connector provides an output where a low-source impedance is desired.

1-4. The Model 651B Test Oscillator output voltage is constantly monitored at the input of the attenuator by an internal voltmeter. The voltmeter has two scales for RMS voltage readings and a dBm scale referenced to 1 milliwatt into 50 ohms. The OUTPUT ATTENUATOR, in conjunction with the AMPLITUDE control, provides a monitored output of desired level when matched into a 50 or 600 ohm load.

## 1-5. AVAILABLE ACCESSORIES.

1-6. Table 1-2 contains a list of the accessories which will increase the usefulness of the Model 651B.

## 1-7. OPTIONS.

1-8. OPTION 01.

1-9. Option 01 is a standard -hp- Model 651B Test Oscillator that has the dBm scale of the output monitor referenced to 1 milliwatt into 600 ohms. The front panel OUTPUT ATTENUATOR dBm markings have been changed to correspond with the signal level at the 600Ω output connector (-80 to +10 DBM).

1-10. OPTION 02.

1-11. Option 02 is a standard -hp- Model 651B Test Oscillator that has output impedances of 75 ohms and 600 ohms. Also, the output monitor has the dBm scale referenced to 1 milliwatt into 75 ohms.

## 1-12. INSTRUMENT IDENTIFICATION.

1-13. Hewlett-Packard uses a two-section eight-digit serial number (000-00000). If the first three digits of the serial number on your instrument do not agree with those on the title page of this manual, change sheets supplied with the manual will define differences between your instrument and the Model 651B described in this manual.

1-14. If a letter prefixes the serial number, the instrument was manufactured outside the United States.

Table 1-2. Available Accessories

| | |
|---|---|
| -hp- Model 10110A, BNC to Binding Post Adapter: Converts a BNC connector to binding post connectors. | -hp- Model 11048B Feed-thru Termination: Precision 50 Ω feed-thru termination with male and female BNC connectors. |
| -hp- Model 11004A Line Matching Transformer: Provides fully balanced 135 Ω or 600 Ω output from single-ended input. | -hp- Model 11095A Feed-Thru Termination: Precision 600 Ω feed-thru termination with male and female BNC connectors. |
| -hp- Model 11005A Line Matching Transformer: Provides fully balanced 600 Ω output from single-ended input. | -hp- Model 11094A Feed-Thru Termination: Precision 75 Ω feed-thru termination with male and female BNC connectors. (Use with Option 02.) |

# SECTION II
# INSTALLATION

## 2-1. INSPECTION.

2-2. This instrument was carefully inspected both mechanically and electrically before shipment. It should be physically free of mars or scratches and in perfect electrical order upon receipt. To confirm this, the instrument should be inspected for physical damage in transit. Also, check for supplied accessories, and test the electrical performance of the instrument using the procedure outlined in Paragraph 5-5. If there is damage or deficiency, see the warranty on the inside front cover of this manual.

## 2-3. POWER REQUIREMENTS.

2-4. The Model 651B will operate from either 115 or 230 Vac, 50 to 1000 Hz. The instrument can be easily converted from 115 to 230 volt operation by changing the position of the slide switch located on the rear panel, so that the designation appearing on the switch matches the nominal voltage of the power source. A 0.4 ampere, slow-blow fuse is used for both 115 and 230 volt operation.

## 2-5. THREE-CONDUCTOR POWER CABLE.

2-6. To protect operating personnel, the National Electrical Manufacturers' Association (NEMA) recommends that the instrument panel and cabinet be grounded. All Hewlett-Packard instruments are equipped with a three-conductor power cable, which, when plugged into an appropriate receptacle, grounds the instrument. The offset pin on the power cable three-prong connector is the ground wire.

2-7. To preserve the protection feature when operating the instrument from a two-contact outlet, use a three-prong to two-prong adapter and connect the green pigtail on the adapter to ground.

## 2-8. INSTALLATION.

2-9. The Model 651B is fully transistorized; therefore no special cooling is required. However, the instrument should not be operated where the ambient temperature exceeds 50$^{\circ}$C.

## 2-10. RACK/BENCH INSTALLATION.

2-11. The Model 651B is initially shipped as a bench-type instrument (unless ordered specifically as a rack type) with plastic feet and a tilt stand in place. Conversion to a rack-mounted instrument can be accomplished by using the rack mounting kit and instructions furnished with your instrument.

## 2-12. REPACKAGING FOR SHIPMENT.

2-13. The following is a general guide for repackaging for shipment. If you have any questions, contact your local -hp- Sales and Service Office. (See Appendix B for office locations.)

NOTE

If the instrument is to be shipped to Hewlett-Packard for service or repair, attach a tag to the instrument, identifying the owner and indicating the service or repair to be accomplished; include the model number and full serial number of the instrument. In any correspondence, identify the instrument by model number, serial number and serial number prefix.

a. Place instrument in original container if available. If original container is not available, a suitable one can be purchased from your nearest -hp- Sales and Service Office.

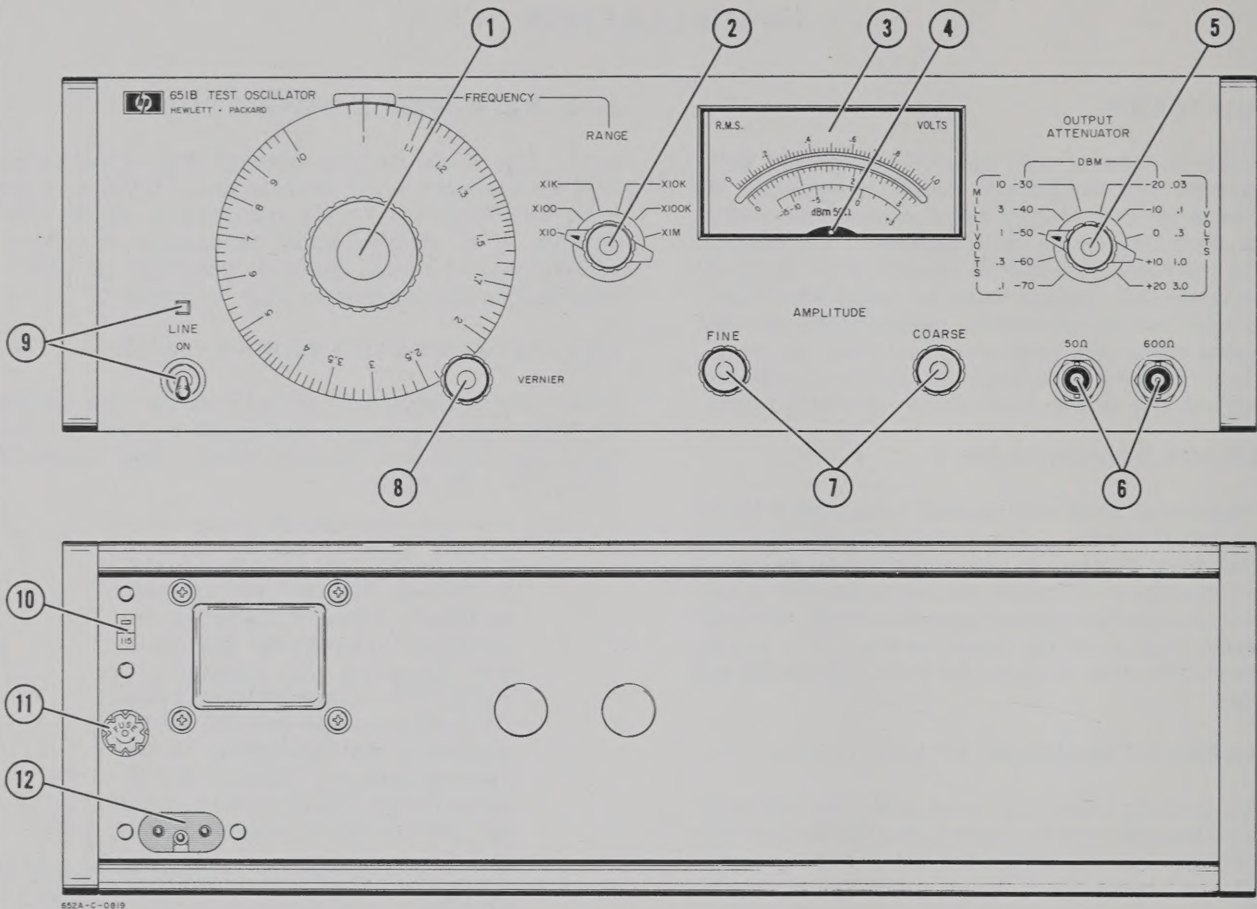
If original container is not used,

b. Wrap instrument in heavy paper or plastic before placing in an inner container.

c. Use plenty of packing material around all sides of instrument and protect panel faces with cardboard strips.

d. Place instrument and inner container in a heavy carton or wooden box and seal with strong tape or metal bands.

e. Mark shipping container with "Delicate Instrument," "Fragile" etc.




1 FREQUENCY Dial: Varies output frequency within each frequency range. Dial reading multiplied by range setting is the output frequency of the instrument.

2 FREQUENCY RANGE Switch (S1): Selects one of six frequency ranges, from 10 Hz to 1 MHz.

3 Output Monitor (M1): Monitors the amplitude of the test oscillator output.

4 Mechanical Zero Adjust: Allows output monitor to be mechanically zeroed, when instrument is off.

5 OUTPUT ATTENUATOR: Attenuates test oscillator output in nine steps of 10 dB each.

6 Output Connectors (J2 and J3): Provides the output signal, at impedance levels of 50Ω and 600Ω. (75Ω and 600Ω on Opt. 02).

7 AMPLITUDE COARSE and FINE Controls: Controls amplitude of signal applied to OUTPUT ATTENUATOR.

8 FREQUENCY VERNIER: Provides a fine frequency adjustment for FREQUENCY dial.

9 LINE ON Switch (S3) and Pilot Lamp: Switch applies primary power to instrument; pilot lamp glows to indicate application of primary power.

10 115/230 V Slide Switch (S4): Sets instrument to operate from a primary power source of either 115 Vac or 230 Vac.

11 FUSE (F1): 0.4 amp fuse protects instrument from overloads.

12 Primary Power Connector (J1): Connects primary power to test oscillator.

Figure 3-1. Location of Controls and Indicators

# SECTION III
# OPERATING INSTRUCTIONS

## 3-1. INTRODUCTION.

3-2. The Model 651B Test Oscillator generates a stable sine wave output that is available at output impedance levels of 600 ohms and 50 ohms. The frequency of the output is variable from 10 Hz to 10 MHz, and the output power level can be varied from 10 microvolts to 3.16 volts into 600 or 50 ohm loads. The amplitude of the output will be indicated on the output monitor, M1.

## 3-3. CONTROLS AND INDICATORS.

3-4. Figure 3-1 identifies and describes the function of all the front and rear panel controls, connectors, and indicators on the Model 651B.

## 3-5. ADJUSTMENT OF MECHANICAL ZERO.

3-6. The output monitor is properly zero-set when the meter pointer rests over the zero mark, and the 651B is in normal operating position at normal operating temperature, and is turned off. Zero-set the output monitor as follows to obtain maximum accuracy and mechanical stability.

a. Turn 651B on and allow it to operate for at least 20 minutes, to let the meter movement reach normal operating temperature.

b. Turn 651B off, and allow 30 seconds for all capacitors to discharge.

c. Insert pointed object (such as tip of ballpoint pen) into recess on adjustment wheel, and rotate wheel until meter pointer is exactly over zero.

## 3-7. OPERATION.

3-8. To operate the 651B Test Oscillator, proceed as follows:

a. Connect primary ac power to 651B (115 or 230 V, 50 Hz to 1000 Hz), and set slide switch S4 to proper position.

b. Turn LINE ON switch to ON position. Indicator lamp will glow, verifying application of primary power.

c. Set FREQUENCY RANGE switch and FREQUENCY dial to desired output frequency.

d. Set OUTPUT ATTENUATOR switch to desired voltage range.

e. Connect load to output connector having an impedance which matches impedance of load.

f. Adjust AMPLITUDE controls for desired output voltage, as indicated on output monitor.

g. The output monitor, M1, indicates the rms value of the output voltage, and the power level in dBm for resistive loads of 50 ohms. The output voltage level is obtained by multiplying the monitor scale readings by the monitor scale multiplier which appears on the OUTPUT ATTENUATOR switch. Use the following equation and the impedance correction graph of Figure 3-2 to obtain the Model 651B output power level in dBm, for loads other than those marked on the output connectors.

$$\text{Output Voltage} = \frac{R_L}{R_L + R_S} \times 2\ V_m$$

Where,

$R_L$ = Load Resistance (Terminating Resistance)

$R_S$ = Source Resistance (Output Impedance of Oscillator)

$V_m$ = Model 651B Output Monitor Reading

Problem: A 600 ohm load is placed on the 50 ohm output connector. The Model 651B output monitor indicates an output of 0.9 volts, with the OUTPUT ATTENUATOR set on the 1.0 volt (+10 dBm) range. Find the actual output voltage and power level (in dBm) of the Model 651B.

Solution: The actual output voltage is calculated as follows:

$$\text{Output Voltage} = \frac{600}{600 + 50} \times 2\ (0.9) = 1.66\ \text{V}$$

The indicated power level for an actual output voltage of 1.66 volts would be +17.3 dBm on the 3.0 V (+20 dBm) range. The actual power level (with the 600 Ω load) is the algebraic sum of the theoretically indicated power level (+17.3 dBm) and a correction factor obtained from the impedance graph of Figure 3-2. For this example, a correction factor of -10.8 dBm is obtained from the 50 Ω output impedance line of the graph with a 600 Ω load. The actual power level then is +6.5 dBm [+17.3 dBm + (-10.8 dBm)].

For Option 01-651B which has the dBm scale of the output monitor referenced to 1 milliwatt into 600 Ω use the 600 Ω output impedance line of graph of Figure 3-2.

For Option 02-651B which has the dBm scale of the output monitor referenced to 1 milliwatt into 75 Ω use the 75 Ω output impedance line of graph of Figure 3-2.

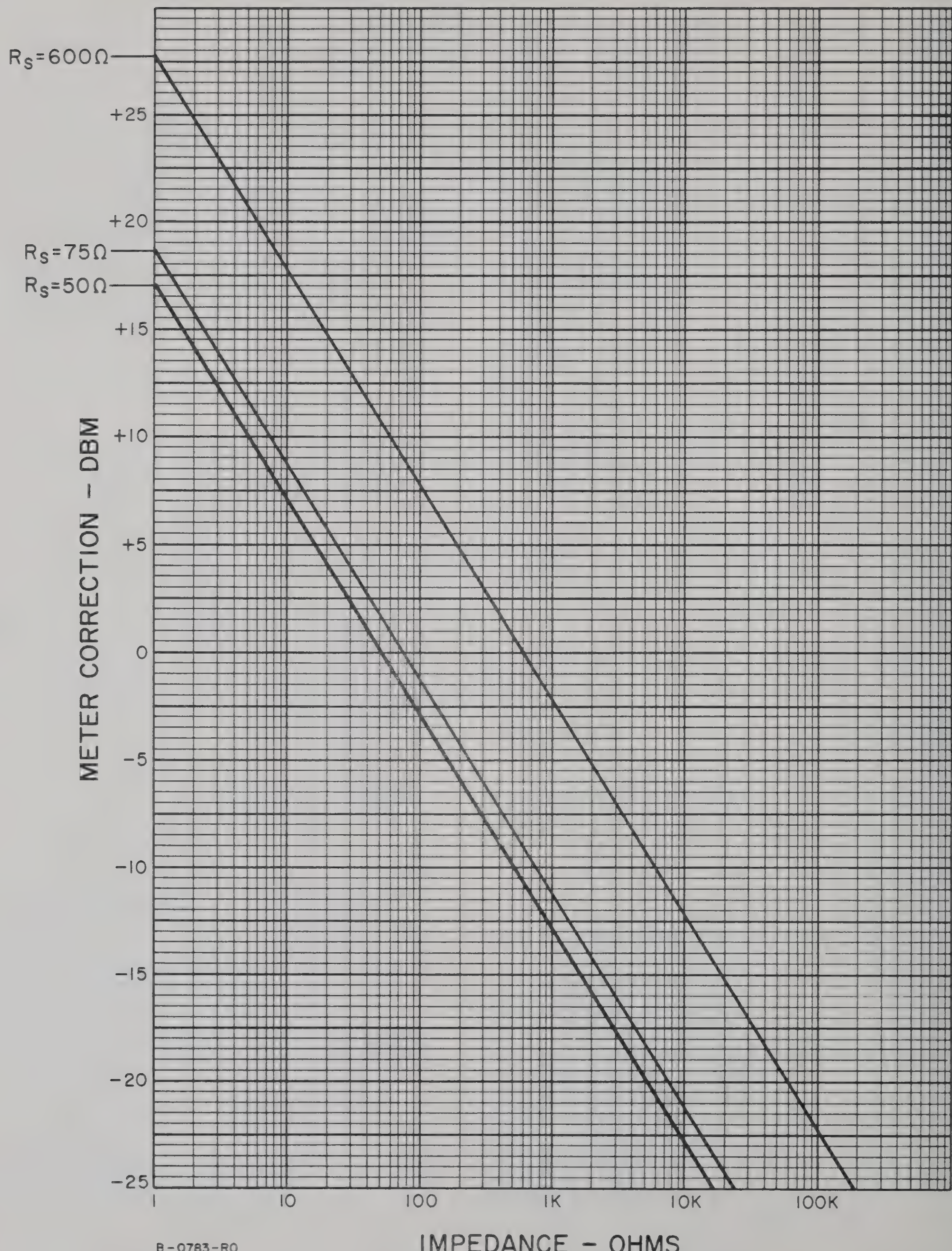



Figure 3-2. Impedance Correction Graph

# SECTION IV
# THEORY OF OPERATION

## 4-1. GENERAL DESCRIPTION.

4-2. The Model 651B Test Oscillator includes an oscillator, power amplifier, peak detector, attenuator, and monitor circuit. A block diagram of the instrument is shown in Figure 6-1. The oscillator circuit uses a modified Wein bridge network to generate a stable, distortionless sine wave signal which is applied to the power amplifier circuit. The peak detector circuit provides a degenerative feedback voltage to the oscillator circuit to stabilize the signal applied to the power amplifier. The power amplifier circuit is used to increase the output power available at the 50 ohm and 600 ohm output connectors and to improve the frequency stability of the output signal with changing output loads. The output attenuator provides a means of attenuating the signal at the output connectors in nine steps of 10 dB each. The monitor circuit continuously monitors the signal level at the input to the attenuator. The regulated power supply provides all voltages required by the 651B circuits.

## 4-3. CIRCUIT DESCRIPTION.

4-4. Refer to Figures 6-2 and 6-3 for the following discussion.

4-5. OSCILLATOR CIRCUIT.

4-6. The oscillator circuit generates a sinusoidal signal at the frequency selected by the RANGE switch and FREQUENCY Dial located on the front panel. The RC bridge network is a modified Wein bridge circuit, consisting of an RC frequency selective network and a resistive voltage divider network. The Wein bridge in the Model 651B Test Oscillator differs from the conventional Wein bridge circuit in the design of the resistive voltage divider network. The resistor in the conventional Wein bridge is replaced with impedance Z1, which consists of A2CR6 and A2CR7.

4-7. Oscillation at the selected frequency is made possible by the use of both positive and negative feedback. Positive feedback is provided through a frequency sensitive RC network to the differential amplifier A2Q2 and A2Q3; negative feedback is provided to the differential amplifier through a network insensitive to frequency. Only at the selected frequency will the positive feedback exceed the negative feedback voltage to sustain oscillation.

4-8. The RANGE switch, S1, selects combinations of resistors and capacitors (S1R1 through S1R24, and S1C1 through S1C14) to establish the frequency sensitive RC networks for the six frequency ranges of the instrument. The FREQUENCY Dial varies the main frequency tuning elements C1A, C1B, and C1C. The RC components maintain the proper phase relationship of the positive feedback voltage. At frequencies where $X_c = R$, the positive feedback voltage is in phase with the oscillator output voltage (refer to Figure 4-1) and exceeds the negative feedback voltage. At frequencies other than where $X_c = R$, the positive feedback voltage is neither of the right phase nor of sufficient amplitude to maintain oscillations.

4-9. A field effect transistor, A2Q1, is used as the impedance converter because of its extremely high input impedance and low noise characteristics. It provides a high impedance in series with the input impedance of the differential amplifier on the lower four frequency ranges (X10 - X10K). The high impedance added prevents the RC bridge circuit from being loaded by the low input impedance of the differential amplifier, A2Q2 and A2Q3, on the lower frequency ranges. The impedance converter is bypassed on the X100K and X1M ranges due to lower resistor values in the RC bridge.

4-10. The difference between the feedback voltages from the bridge circuit is amplified by differential amplifier A2Q2 and A2Q3, and is applied to the complementary symmetry circuit A2Q5 and A2Q6, through emitter follower A2Q4. A positive feedback voltage from the output of the complementary symmetry circuit is applied between resistors A2R8 and A2R9, in the collector circuit of A2Q2, on the first four frequency ranges. The application of the feedback voltage at this point is used to make the effective resistance of the collector load higher than the input impedance of the emitter follower A2Q4, forcing the collector current into the base of the emitter follower. The increase in the base current results in an increase in the loop gain of the oscillator circuit. The feedback voltage is removed on the X100K and X1M frequency ranges due to the value of resistors A2R8 and A2R9 exceeding the input impedance of the emitter follower at the higher frequencies.

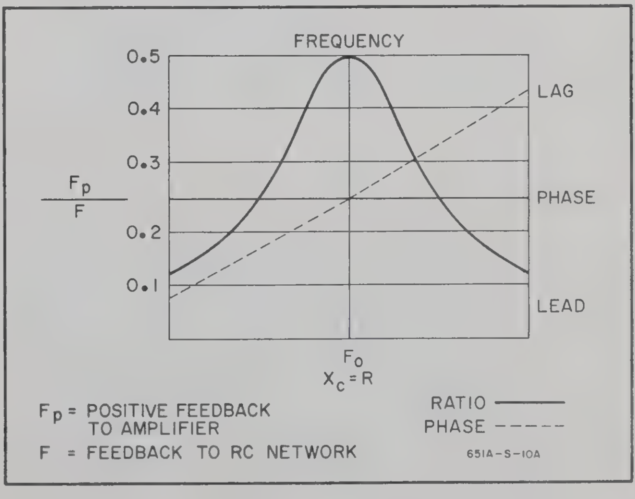



Figure 4-1. RC Network Characteristics

4-11. The complementary symmetry circuit is used to provide power gain and to increase the dynamic voltage range of the oscillator; also, the low output impedance of the complementary symmetry circuit prevents the oscillator output circuit from being loaded by the RC bridge. The complementary symmetry circuit transistors are forward-biased by diodes A2CR2, A2CR3, and A2CR4, and with no signal applied, are conducting slightly to reduce cross-over distortion in the output signal.

4-12. The output of the oscillator circuit drives the power amplifier with a constant voltage set by the AMPLITUDE COARSE and FINE controls, R2 and R3. The voltage level applied to the power amplifier is held constant by the action of the peak detector circuit.

4-13. AUTOMATIC GAIN CONTROL.

4-14. The output of the oscillator circuit is superimposed on a negative reference bias at the base of A2Q7. This bias voltage is determined by the setting of the amplitude controls. The peak detector, A2Q7, will conduct only on the positive peaks when the negative bias is overcome. The average dc voltage across A2C7, A2C8 or A2C9 biases the two diodes A2CR6, A2CR7 so it determines the impedance of the negative feedback side of the Wein bridge. Thus the amplitude of the oscillations is automatically controlled. A2CR5 and A2CR9 provide temperature compensation for the bias voltage on A2Q7, and A2CR8 prevents the reverse breakdown of A2Q7. A2R17 is adjustable to compensate for differences in the operating characteristics of diodes A2CR6 and A2CR7, minimizing distortion in the negative feedback and subsequently in the oscillator output.

4-15. POWER AMPLIFIER.

4-16. The power amplifier circuit increases the power gain of the signal received from the oscillator circuit. The operation of the differential amplifier A2Q8 and A2Q9, emitter follower A2Q10, and complementary symmetry circuit A2Q11 and A2Q12 is similar to the corresponding stages in the oscillator circuit. The negative feedback voltage from the output of the complementary symmetry circuit is applied to the differential amplifier at a fixed level to stabilize the power amplifier output signal. The power amplifier output is continuously monitored by the monitor circuit before the signal is applied to the output attenuator circuit.

4-17. MONITOR CIRCUIT.

4-18. The monitor circuit monitors the signal level applied to the output attenuator circuit and provides a signal to the output monitor M1, which indicates the amplitude of the output in RMS volts and dBm. The amplifier A1Q9 serves both as an impedance converter between the monitor circuit and the power amplifier output circuit, and as a current source to provide full-scale monitor indications. The high input impedance of A1Q9 prevents the power amplifier from being loaded with the low impedance of the output monitor, M1. The emitter follower, A1Q8, provides a positive feedback voltage which is applied between resistors A1R18 and A1R19, in the collector lead of amplifier A1Q9. The application of the feedback voltage at this point is used to increase the effective resistance of the collector circuit, which results in the amplifier A1Q9 appearing as a high impedance current source to the monitor. Diode A1CR10 provides a small amount of forward bias to rectifier diodes A1CR8 and A1CR9, which keeps the diodes out of the non-linear region, thus increasing monitor accuracy at one-tenth full-scale readings. The 10 MHz adjustment, A1C15, compensates for small variations in circuit capacitance so the monitor will have a flat frequency response. The monitor calibration resistor, A1R23, provides an additional calibration adjustment which is made at 400 Hz.

4-19. OUTPUT ATTENUATOR.

4-20. The output attenuator provides a means of attenuating the signal level applied to the 50 ohm and 600 ohm output connectors. The OUTPUT ATTENUATOR switch, S2, selects a combination of four resistor networks to produce the desired level of signal attenuation. Each step provides an attenuation of 10 dB. The AMPLITUDE controls, R2 and R3, vary the level of attenuation in increments between each 10 dB step selected by the OUTPUT ATTENUATOR switch.

4-21. Output impedances other than the standard 50 and 600 ohms can be obtained by changing the value of resistors S2R14 or S2R13. The value of the replacement resistor is added to the 50 ohm oscillator output to give the required output impedance.

4-22. REGULATED POWER SUPPLY.

4-23. The regulated power supply provides all voltages required by the test oscillator circuits. The power supply consists of a +30 volt series regulated supply and a -25 volt series regulated supply which is referenced to the +30 volt circuit.

4-24. The +30 volt regulated supply is of the conventional series regulator type. The emitter follower A1Q2 is used to increase the loop gain of the circuit, thus improving voltage regulation. The +30 volt adjustment, A1R4, sets the +30 volt and -25 volt supply output level.

4-25. The -25 volt regulated supply is of the conventional series regulator type and operates the same as the +30 volt supply. A current limiter, A1Q7, has been added to limit the load current to a set value. When the load current exceeds the set value, the current limiter conducts, causing the series regulator Q2 to reduce the output voltage level until the load causing an excessive current is removed. Diodes A1CR6 and A1CR7 protect the control transistor A1Q6, against short circuits between the two voltage supplies, or short circuits in the output of the -25 volt supply.

Table 5-1. Required Test Equipment

| INSTRUMENT TYPE | REQUIRED CHARACTERISTICS | RECOMMENDED MODEL |
|---|---|---|
| Oscilloscope | Passband: 10 Hz to 10 MHz<br>Sensitivity: 50 mV/cm<br>Input Impedance: 1 megohm | -hp- Model 180A Oscilloscope |
| Electronic Counter | Range: 10 Hz to 10 MHz<br>Accuracy: ±5 counts | -hp- Model 5245L Electronic Counter |
| RMS Voltmeter | Frequency Range: 10 Hz to 10 MHz<br>Voltage Range: 1 mV to 10 V<br>Accuracy: ±1% | -hp- Model 3400A RMS Voltmeter (with known error) |
| Distortion Analyzer | Distortion Sensitivity: >42 dB | -hp- Model 331A |
| Wave Analyzer | Frequency Range: 600 kHz to 22 MHz | -hp- Model H05-312A |
| DC Null Voltmeter | Range: 10 $\mu$V to 30 V<br>Accuracy: ±2% of full scale | -hp- Model 419A |
| † AC Differential Voltmeter | Range: 1 V to 10 V<br>Accuracy: ±0.1%<br>Stability: ±0.1% Per Mo. | -hp- Model 741B AC-DC Differential Voltmeter/DC Standard |
| Attenuator | Attenuation Range: 90 dB in 10 dB steps<br>Frequency Range: 10 Hz to 10 MHz | -hp- Model 355D VHF Attenuator (with known error) |
| Amplifier | Gain: 40 dB<br>Frequency Range: 10 Hz to 10 MHz | -hp- Model 461A Amplifier |
| Thermal Converter | Input: 3 V RMS<br>Output: 7 mV dc<br>Accuracy: ±0.2%<br>Frequency Range: 10 Hz to 10 MHz<br>Input Impedance:<br>a. 50 Ω<br>b. 75 Ω (Use with Option 02-651B only) | Thermal Converter<br>a. -hp- Model 11049A<br>b. -hp- Model H01-11049A |
| 0 to 10 mV Reference Supply | See Figure 5-3 for schematic<br>a. Resistor: fxd, 6500 Ω ±1%<br>b. Resistor: var, 500 Ω ±5%<br>c. Resistor: var, 50 Ω ±5%<br>d. Battery: 1.34 V | a. -hp- Part No. 0811-0392<br>b. -hp- Part No. 2100-0324<br>c. -hp- Part No. 2100-1481<br>d. Mallory RM-42R |
| Terminating Resistance | a. Feed-thru, 50 Ω<br>b. Feed-thru, 600 Ω<br>c. Feed-thru, 75 Ω (with Option 02-651B only) | a. -hp- Model 11048B<br>b. -hp- Model 11095A<br>c. -hp- Model 11094A |
| Adapter | BNC to Binding Post | -hp- Model 10111A Adapter |
| † Recorder | Chart Speed: 1"/hr or less | -hp- Model 680 6" Strip Chart Recorder |
| DC Voltmeter | Range: 0.1 V to 30 V<br>Accuracy: ±1% of Full Scale | -hp- Model 412A DC VTVM |
| Impedance Converter (Use with Option 02-651B only) | 75 Ω to 50 Ω | See Figure 5-4b for parts list. |

† These instruments required only if Amplitude Stability Check (Paragraph 5-18) is performed.

# SECTION V
# MAINTENANCE

## 5-1. INTRODUCTION.

5-2. This section contains maintenance and service information for the -hp- Model 651B Test Oscillator. Included are Performance Checks, Adjustment and Calibration Procedures, and Troubleshooting Procedures.

## 5-3. REQUIRED TEST EQUIPMENT.

5-4. The equipment needed to properly maintain the Model 651B is listed in Table 5-1. The table lists the type of equipment to be used, the specification requirements, and the recommended commercially available test equipment. If the equipment listed in Table 5-1 is not available, any instrument that satisfies the given specifications may be used.

## 5-5. PERFORMANCE CHECKS.

5-6. The performance checks are in-cabinet checks which insure the Model 651B Test Oscillator is operating within specifications.‡ These checks can be used for incoming inspection, periodic maintenance, and for specification checks after a repair. Use the performance checks to verify instrument performance before making internal adjustments or repairs. It is recommended that performance checks and calibration be performed at 6 month intervals. A removeable test card is located at the end of Section V. This may be used for making a permanent record of the performance of the 651B during the Performance Checks.

NOTE

The Performance Checks and Calibration Procedures are written for a standard 651B with a 50 Ω output; These checks apply to the options as follows:

Option 01-651B - no changes necessary.

Option 02-651B - all checks apply to the 75 Ω output except where noted in the test and on the diagrams.

## 5-7. FREQUENCY RANGE CHECK.

a. Connect 651B 50 Ω output to dc input of electronic counter as shown in Figure 5-1. With Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X10 |
| FREQUENCY dial . . . . . . | Extreme Clockwise |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE . . . . . . . . | 3.0 V on monitor |

c. Counter should read a period average of 100 ms or greater, verifying a frequency of at least 10 Hz at lower end of frequency range.

d. Set 651B FREQUENCY RANGE to X1M and FREQUENCY dial to extreme counter-clockwise position. Counter should read a frequency of 10 MHz or greater verifying a frequency of at least 10 MHz at upper end of frequency range.

e. Perform Frequency Calibration, Paragraphs 5-26 through 5-33, if tolerances are not met.

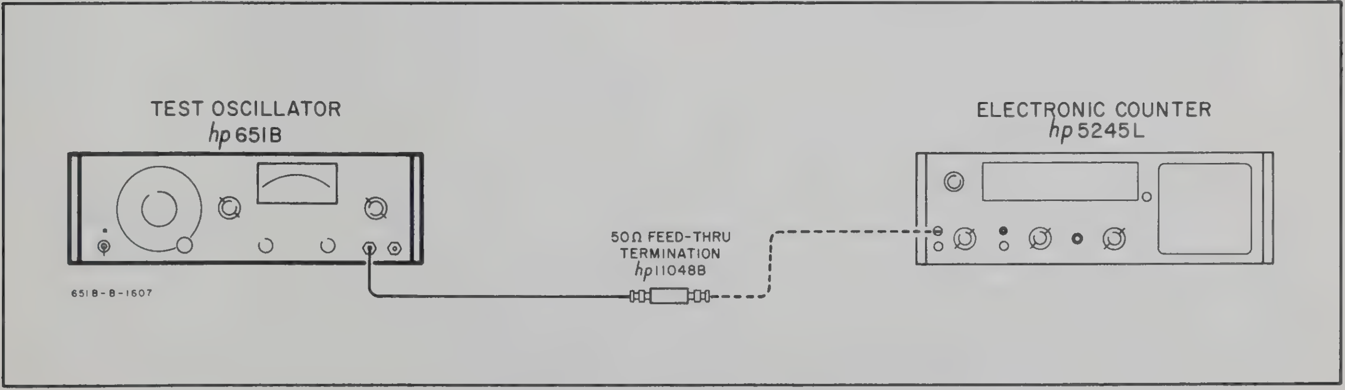



Figure 5-1. Frequency Checks

‡ Paragraphs 5-17 and 5-18 are labelled 'Optional' checks for the following reasons:
Paragraph 5-17 HUM AND NOISE CHECK: top cover of 651B must be removed to make this check.
Paragraph 5-18 AMPLITUDE STABILITY CHECK: 651B output amplitude must be monitored continuously for one month to make this check.

## 5-8. DIAL ACCURACY CHECK.

a. Connect 651B 50 Ω output to dc input of electronic counter as shown in Figure 5-1. With Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X10
FREQUENCY dial . . . . . . 1
OUTPUT ATTENUATOR . . 3.0 V
AMPLITUDE . . . . . . . . 3.0 V on monitor

c. Check all frequency settings given in Table 5-2. Counter should read period average for frequencies below 1 kHz and frequency for higher frequencies. Table 5-2 lists the check frequencies and tolerances required.

d. Perform Frequency Calibration in Paragraphs 5-26 through 5-33 if tolerances are not met.

Table 5-2. Dial Accuracy Check

| FREQUENCY DIAL | RANGE | COUNTER INDICATION |
|---|---|---|
| | | (counter set to read period average) |
| 1 | X10 | 100 ± 3 ms |
| 5 | X10 | 20.0 ± 0.6 ms |
| 10 | X10 | 10.0 ± 0.3 ms |
| 1 | X100 | 10.0 ± 0.2 ms |
| 5 | X100 | 2.00 ± 0.04 ms |
| 10 | X100 | 1.00 ± 0.02 ms |
| | | (counter set to read frequency) |
| 1 | X1K | 1,000 ± 20 Hz |
| 5 | X1K | 5,000 ± 100 Hz |
| 10 | X1K | 10.0 ± 0.2 kHz |
| 1 | X10K | 10.0 ± 0.2 kHz |
| 5 | X10K | 50.0 ± 1.0 kHz |
| 10 | X10K | 100.0 ± 2.0 kHz |
| 1 | X100K | 100.0 ± 2.0 kHz |
| 5 | X100K | 500.0 ± 10.0 kHz |
| 10 | X100K | 1,000 ± 20 kHz |
| 1 | X1M | 1,000 ± 30 kHz |
| 5 | X1M | 5,000 ± 150 kHz |
| 10 | X1M | 10,000 ± 300 kHz |

## 5-9. OUTPUT CHECKS.

### 5-10. MAXIMUM VOLTAGE.

a. Connect rms voltmeter to 50 Ω output terminal of 651B as shown in Figure 5-2. With Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X1K
FREQUENCY dial . . . . . . 10
OUTPUT ATTENUATOR . . 3.0 V

c. Adjust 651B AMPLITUDE controls for maximum output; rms voltmeter should indicate 3.16 V or greater.

d. Disconnect rms voltmeter from 50 Ω output terminal of 651B and connect to 600 Ω output. Replace 50 Ω load with a 600 Ω load.

e. Repeat step c.

f. Perform Amplitude Adjustment in Paragraph 5-37 if tolerances are not met.

### 5-11. FLATNESS CHECK (Amplitude not readjusted to a reference on the output monitor).

a. Connect equipment as shown in Figure 5-3. (Use a thermal converter with a known change in output for a given change at the input. If this information is not readily available, then Table 5-3 gives this information for a typical thermal converter connected as in Figure 5-3.) Set both 651B output and reference supply to minimum before connecting. Thermal converter must be connected directly to 50 Ω output of 651B. With Option 02-651B, use 75 Ω thermal converter (-hp- Model H01-11049A).

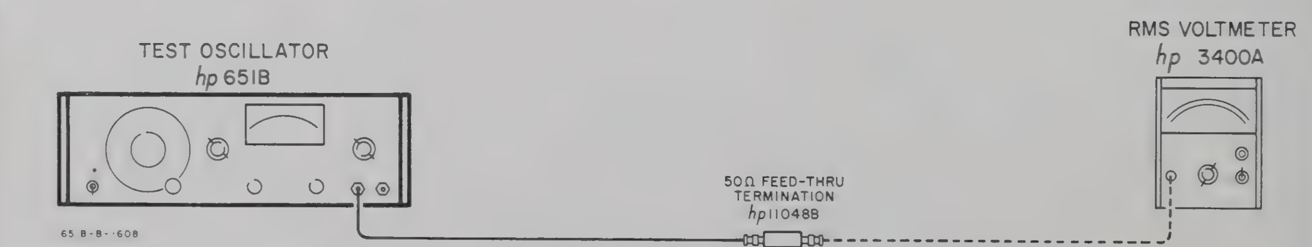



Figure 5-2. Output Checks

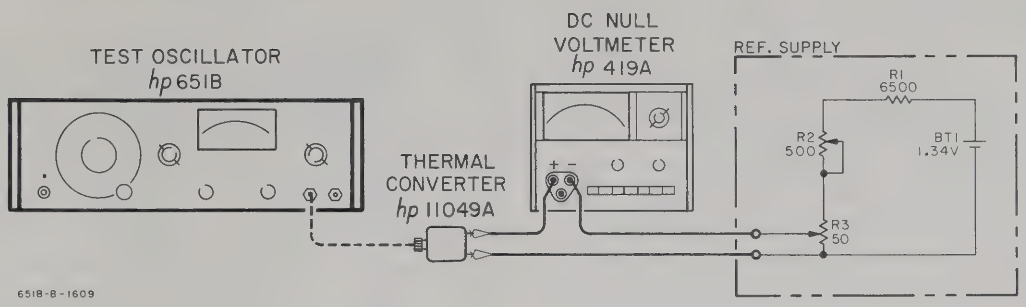



Figure 5-3. Flatness Checks

**CAUTION**

DO NOT EXCEED RATED INPUT OF THERMAL CONVERTER. ANY OVERLOAD OR HIGH VOLTAGE TRANSIENT MAY DESTROY THERMOELEMENT. WHEN USING THE 651B FREQUENCY RANGE SWITCH, MOMENTARILY TURN DOWN THE OUTPUT ATTENUATOR.

Table 5-3. Flatness Checks

| CHANGE AT AC INPUT OF THERMAL CONVERTER | CHANGE OF DC NULL METER INDICATION FROM NULL SETTING |
|---|---|
| ±1% | ±140 $\mu$V |
| ±2% | ±280 $\mu$V |
| ±3% | ±420 $\mu$V |
| ±4% | ±560 $\mu$V |
| The ac input is set for 7.0 mV dc at the output of the thermal converter. | |

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X1K
FREQUENCY dial . . . . . . 10
OUTPUT ATTENUATOR . . 3.0 V

c. Adjust 651B AMPLITUDE controls for dc null meter indication of 7.0 mV.

d. Adjust reference supply for null indication. Do not readjust reference supply or 651B AMPLITUDE controls once null is obtained.

e. Adjusting 651B FREQUENCY RANGE switch and FREQUENCY dial as necessary, sweep 651B slowly over frequency range of 100 Hz to 1 MHz. Dc null meter reading will change above or below (or both) the null obtained in step d. Record minimum and maximum readings of dc null meter; difference between these two readings should indicate a change in level of 651B output no greater than ±2% (see Table 5-3) verifying flatness specification over frequency range of 100 Hz to 1 MHz.

f. Repeat step e over the range 10 Hz to 1 MHz. The difference between dc null meter maximum and minimum readings should indicate a change in level of 651B output no greater than ±3% (see Table 5-3) verifying flatness specification over frequency range of 10 Hz to 1 MHz.

g. Repeat step e over the range of 10 Hz to 10 MHz. The difference between dc null meter maximum and minimum readings should indicate a change in level of 651B output no greater than ±4% (see Table 5-3) verifying flatness specification over frequency range of 10 Hz to 10 MHz.

h. Perform Frequency Calibration (Paragraphs 5-26 through 5-33) and 10 MHz Flatness Adjustment (Paragraph 5-34) if tolerances not met.

5-12. FLATNESS (Amplitude readjusted to a reference on the output monitor).

a. Perform step 5-11a. (Note CAUTION.)

b. Set 651B controls as follows:

FREQUENCY RANGE . . . . X10
FREQUENCY dial . . . . . . 2
OUTPUT ATTENUATOR . . 3.0 V
AMPLITUDE . . . . . . . . Adjust for a monitor indication of 3.0 V. (This adjustment is critical as this will be the reference level for steps 5-12c through h.)

c. Adjust reference supply for null indication on dc null meter.

d. Set 651B FREQUENCY dial for 10 Hz.

e. Readjust 651B AMPLITUDE controls for 3.0 V on 651B OUTPUT MONITOR. (Do not readjust reference supply.) Record dc null meter indication.

f. Set 651B FREQUENCY dial for 12 Hz and repeat step 5-12e.

g. Set 651B FREQUENCY dial for 15 Hz and repeat step 5-12e.

h. To determine that the readings taken in steps 5-12e, f, and g are within tolerance, two conditions must be met:

1) Each reading must be within 2% of the reference level established in Step 5-12b. (See Table 5-3.)

2) The difference between the highest and lowest reading must be no greater than 2% of the reference level established in Step 5-12b.

These two conditions verify 651B output flatness, when referenced to the monitor, of 2% between 10 Hz and 20 Hz.

i. Repeat steps 5-12b through h (except, set up reference at 20 Hz and use the frequencies and tolerances listed in Table 5-4) to verify flatness of 1% over frequency range of 20 Hz to 4 MHz.

j. Repeat steps 5-12b through h (except, set up reference level at 4 MHz and use the frequencies and tolerances listed in Table 5-4) to verify flatness of 2% over frequency range of 4 MHz to 10 MHz.

k. If tolerances are not met, first assure that tolerances of Paragraph 5-11 are met, then perform Output Monitor Calibration of Paragraph 5-39.

5-13. OUTPUT MONITOR ACCURACY CHECK.

a. Connect rms voltmeter to 50 Ω output terminal of 651B as shown in Figure 5-2. For Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A). Use an rms voltmeter with known error at frequency to be used (400 Hz).

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X100
FREQUENCY dial . . . . . . 4
OUTPUT ATTENUATOR . . 3.0 V

Table 5-4. Flatness Check
(Amplitude readjusted to a reference on the output monitor)

| FREQUENCY RANGE | FREQUENCY DIAL | TOLERANCE |
|---|---|---|
| (10 Hz to 20 Hz) | | |
| X10 | 1 | 2% |
| X10 | 1.2 | 2% |
| X10 | 1.5 | 2% |
| X10 | 2 | 2% |
| (20 Hz to 4 MHz) | | |
| X10 | 2 | 1% |
| X100 | 1 | 1% |
| X100 | 5 | 1% |
| X1K | 1 | 1% |
| X1K | 5 | 1% |
| X10K | 1 | 1% |
| X10K | 5 | 1% |
| X100K | 1 | 1% |
| X100K | 5 | 1% |
| X1M | 1 | 1% |
| X1M | 4 | 1% |
| (4 MHz to 10 MHz) | | |
| X1M | 4 | 2% |
| X1M | 6 | 2% |
| X1M | 8 | 2% |
| X1M | 10 | 2% |

c. Set AMPLITUDE controls for a 3.0 V indication on 651B monitor. Rms voltmeter should indicate 3 V ±0.06 V (±2%), verifying an output monitor accuracy of ±2% of full scale.

d. If tolerance is not met, perform Output Monitor Calibration, Paragraph 5-39.

5-14. ATTENUATOR CHECK.

a. Connect external attenuator, amplifier and rms voltmeter to 651B as shown in Figure 5-4a. Use an attenuator with known error. For Option 02-651B, connect impedance converter (Figure 5-4b) in series between 75 Ω output of Option 02-651B and attenuator. 75 Ω input of impedance converter connects to Option 02-651B; 50 Ω end connects to attenuator.

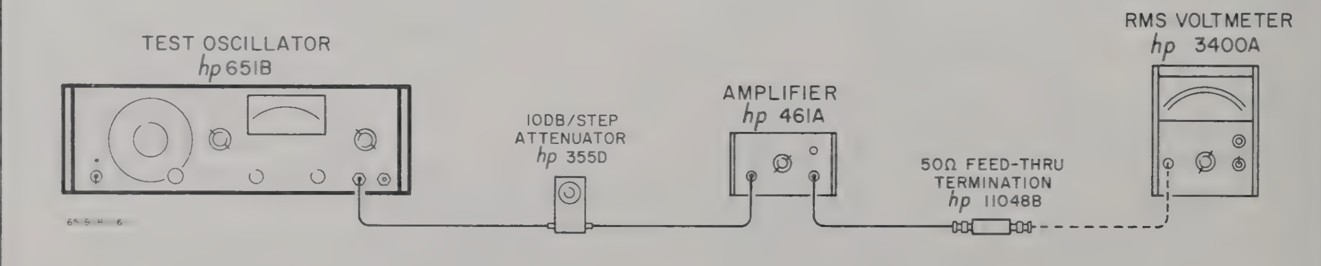



Figure 5-4a. Attenuator Check

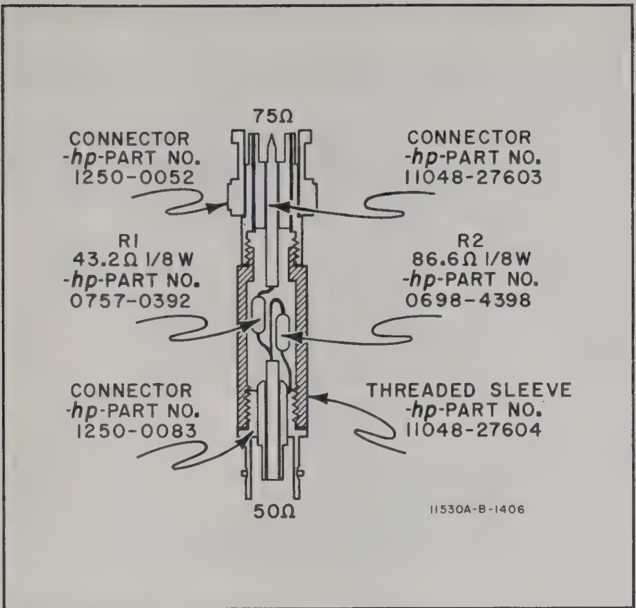



Figure 5-4b. 75 Ω to 50 Ω Impedance Converter

NOTE

Float amplifier and rms voltmeter using an isolation transformer to isolate chassis ground from power line ground.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X1K |
| FREQUENCY dial . . . . . . | 1 |
| OUTPUT ATTENUATOR . . | 3.0 V |

c. Set attenuator switch to 90 dB position.

d. Set amplifier gain switch to 40 dB position.

e. Adjust 651B AMPLITUDE controls for a 9.0 mV indication on rms voltmeter. (Adjust Option 02-651B AMPLITUDE controls for a 3.0 mV indication on rms voltmeter.)

f. Check 651B OUTPUT ATTENUATOR in each position by decreasing attenuation on external attenuator as attenuation is increased on 651B. Rms voltmeter indication should be:

1) 9 mV ±0.09 mV (for Option 02-651B read 3 mV ±0.03 mV) for 0.3 mV through 3.0 V ranges (-60 dB to +20 dB) verifying an overall accuracy of ±0.075 dB, -60 dBm to +20 dBm.

2) 9 mV ±0.18 mV (for Option 02-651B read 3 mV ±0.06 mV) for 0.1 mV range (-70 dB) verifying an overall accuracy of ±0.2 dB, -70 dBm to -60 dBm.

g. Repeat steps c through f of this paragraph with 651B frequency set to 10 MHz.

5-15. AMPLITUDE CONTROL CHECK.

a. Connect rms voltmeter to 50 Ω output terminal of 651B as shown in Figure 5-2. For Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X100 |
| FREQUENCY dial . . . . . . | 4 |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE (COARSE and FINE) . . . . . . . . . . . | Extreme Clockwise |

c. Note reading on rms voltmeter.

d. Set AMPLITUDE COARSE and FINE controls to extreme counterclockwise position. Rms voltmeter should read 20 dB or more below reading noted in step c. This verifies an amplitude control of at least 20 dB.

5-16. DISTORTION CHECK.

a. Connect distortion analyzer to 651B as shown in Figure 5-5. For Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X1K |
| FREQUENCY dial . . . . . . | 1 |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE . . . . . . . . | Adjust for monitor indication of 3.0 V. |

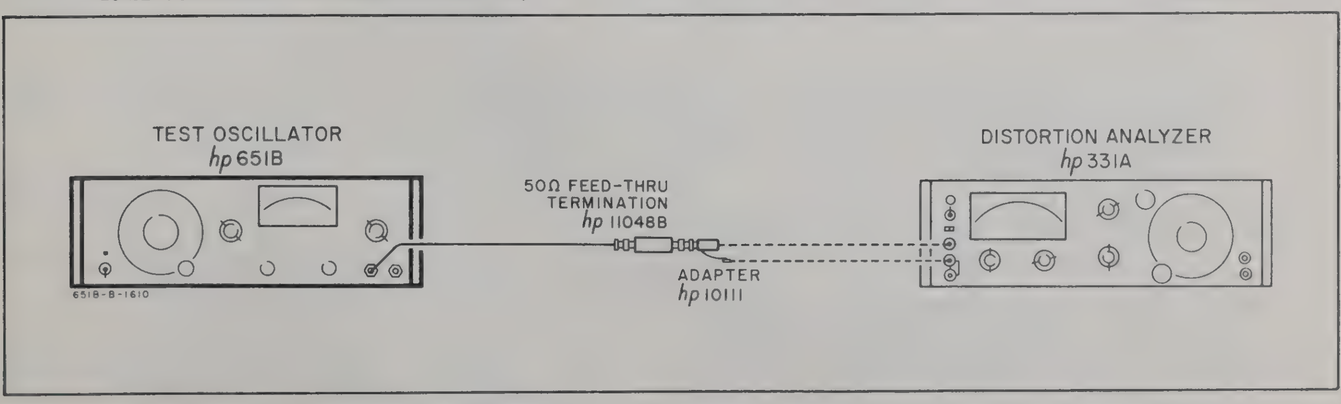



Figure 5-5. Distortion Check

c. Distortion level, as indicated on distortion analyzer, should be less than 1%.

d. Repeat steps b and c to check distortion at each of frequency settings shown in Table 5-5 (Part A).

e. Disconnect 651B output from distortion analyzer and connect to wave analyzer (remove 50 Ω feed-thru termination).

f. Check distortion at each of frequency settings shown in Table 5-5 (Part B). Use the following formula to compute distortion.

$$\% \text{ distortion} = \frac{100\sqrt{{E_2}^2 + {E_3}^3 + \ldots}}{E_1}$$

$E_1$ = rms voltage of fundamental frequency;
$E_2$ = rms voltage of second harmonic;
$E_3$ = rms voltage of third harmonic;
etc. . . .

g. Perform Minimum Distortion Adjustment, Paragraph 5-38, if tolerances are not met.

Table 5-5. Distortion Check

| FREQUENCY RANGE | FREQUENCY DIAL | DISTORTION |
|---|---|---|
| Part A | | |
| X10 | 1 | <1% |
| X100 | 1 | <1% |
| X1K | 1 | <1% |
| X10K | 1 | <1% |
| X100K | 1 | <1% |
| X100K | 5 | <1% |
| Part B | | |
| X1M | 2 | <1% |
| X1M | 5 | <2% |
| X1M | 10 | <4% |

5-17. HUM AND NOISE CHECK (OPTIONAL).

a. Connect rms voltmeter to 50 Ω output of 651B as shown in Figure 5-2. For Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X100
FREQUENCY dial . . . . . . 10
OUTPUT ATTENUATOR . . 3.0 V

c. Adjust 651B AMPLITUDE controls for a reading of 0 dB on 3 V range of rms voltmeter.

d. Remove top cover of 651B and short out tuner by clipping a lead from the solder lug on tuner frame to chassis. Residual hum and noise should read greater than -66 dB from 0 dB reference set on rms voltmeter in step c.

e. Remove clip lead and replace 651B top cover.

5-18. AMPLITUDE STABILITY CHECK (OPTIONAL).

a. Connect ac differential voltmeter and strip chart recorder to 651B as shown in Figure 5-6. For Option 02-651B, use 75 Ω feed-thru termination (-hp- Model 11094A).

NOTE

Float ac differential voltmeter by using an isolation transformer to isolate chassis ground from ac power line ground.

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X1K
FREQUENCY dial . . . . . . 1
OUTPUT ATTENUATOR . . 3.0 V

c. Adjust 651B AMPLITUDE controls for a 3.000 V indication on differential voltmeter.

d. Set recorder output adjustment of ac differential voltmeter so that a ±0.06 V variation of 651B output can be easily recorded.

e. The output of 651B should not vary by more than ±2.0% over a period of one month when temperature remains between 20°C and 30°C.

5-19. OUTPUT IMPEDANCE CHECK.

a. Connect 50 Ω output (75 Ω output of Option 02-651B) of 651B directly to rms voltmeter.

b. Set 651B controls as follows:
FREQUENCY RANGE . . . . X1K
FREQUENCY dial . . . . . . 1
OUTPUT ATTENUATOR . . 3.0 V

c. Adjust 651B AMPLITUDE controls for a 6.0 V indication on rms voltmeter.

d. Insert 50 Ω feed-thru load (75 Ω load for Option 02-651B) between 651B and rms voltmeter. Rms voltmeter indication should drop to 3.0 V ±0.15 V, verifying a 50 Ω (75 Ω for Option 02-651B) output impedance.

e. Remove 50 Ω feed-thru load and disconnect cable to 50 Ω output of 651B.

f. Connect 600 Ω output of 651B directly to rms voltmeter.

g. Adjust 651B AMPLITUDE controls for a 6.0 V indication on rms voltmeter.

h. Insert a 600 Ω load between 651B and rms voltmeter. Rms voltmeter indication should drop to 3.0 V ±0.15 V, verifying a 600 Ω output impedance.

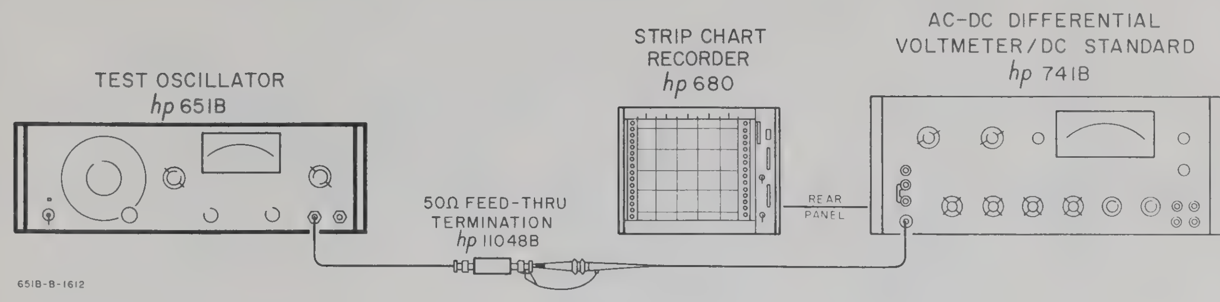



Figure 5-6. Amplitude Stability Check

## 5-20. ADJUSTMENT AND CALIBRATION PROCEDURE.

5-21. The following is a complete adjustment and calibration procedure for the Model 651B. The adjustments should be performed only if it has been determined by the Performance Checks that the 651B is not within specifications. Figure 5-7 shows the location of all internal adjustments.

5-22. COVER REMOVAL.

5-23. To remove top or bottom cover, remove two retaining screws from sides of cover; slide cover about 1/2 inch to rear; lift it off. To replace cover, reverse procedure.

5-24. To remove side cover, remove two retaining screws in cover and lift it off.

5-25. POWER SUPPLY VOLTAGE ADJUSTMENTS.

a. Connect dc voltmeter to power supply positive output, connector point 1. (Refer to Figure 6-3.)

b. Adjust A1R4 (+30 V adjust) for an indication of +30 V on dc voltmeter. If A1R4 does not have sufficient range, change A1R5*.

c. Connect dc voltmeter to power supply negative output, connector point 2; dc voltmeter should indicate -25 V ±0.75 V. If negative supply output is not within tolerance, change value of resistor A1R13* to obtain specified output. Decrease value of A1R13* to increase negative supply voltage; increase value of A1R13* to decrease negative supply voltage.

5-26. FREQUENCY CALIBRATION PROCEDURES.

a. The frequency calibration setup is shown in Figure 5-8. Output frequency should be continuously monitored at the 50 Ω output with a counter. Dc voltage at A2TP2 should also be monitored continuously, after Paragraph 5-27 has been performed.

b. Table 5-8 lists frequency accuracy required at each check frequency.

NOTE

If any adjustments are necessary, the top and bottom covers should be in place when final frequency and A2TP2 voltage checks are made.

c. The adjustments available for each range are listed in Table 5-7. Some of these components

CAUTION

THE 651B CONTAINS HIGH IMPEDANCE, HIGH FREQUENCY CIRCUITS. CONTAMINATION OF THE SWITCHES, CIRCUIT BOARDS OR TUNING CAPACITOR WILL CAUSE HIGH IMPEDANCE LEAKAGE PATHS AND SUBSEQUENT DETERIORATION OF THE PERFORMANCE OF THE INSTRUMENT. AVOID TOUCHING ANY OF THESE CIRCUITS WITH THE BARE FINGERS, AS SKIN OILS ARE EXTREMELY CONTAMINATING. IF HANDLING IS NECESSARY, WEAR CLEAN COTTON OR RUBBER GLOVES. DO NOT USE A PENCIL TO TRACE CIRCUITS IN THE INSTRUMENT. GRAPHITE PENCIL LEAD IS AN EXTREMELY GOOD CONDUCTOR AND AN ACCIDENTALLY INTRODUCED PATH OF THIS TYPE IS SOMETIMES DIFFICULT TO LOCATE. TO AVOID SURFACE CONTAMINATION OF A PRINTED CIRCUIT OR SWITCH, CLEAN WITH A WEAK SOLUTION OF WARM WATER AND MILD DETERGENT AFTER REPAIR. RINSE THOROUGHLY WITH CLEAN WATER AND ALLOW IT TO DRY COMPLETELY BEFORE OPERATING. DO NOT USE ALCOHOL OR ANY OTHER CLEANING SOLUTION EXCEPT MILD DETERGENT AND WATER. DO NOT APPLY ANY COMMERCIAL MOISTURE SEALING SPRAY TO THE BOARDS; APPLICATION OF THESE AGENTS MAY CAUSE LEAKAGE PATHS.

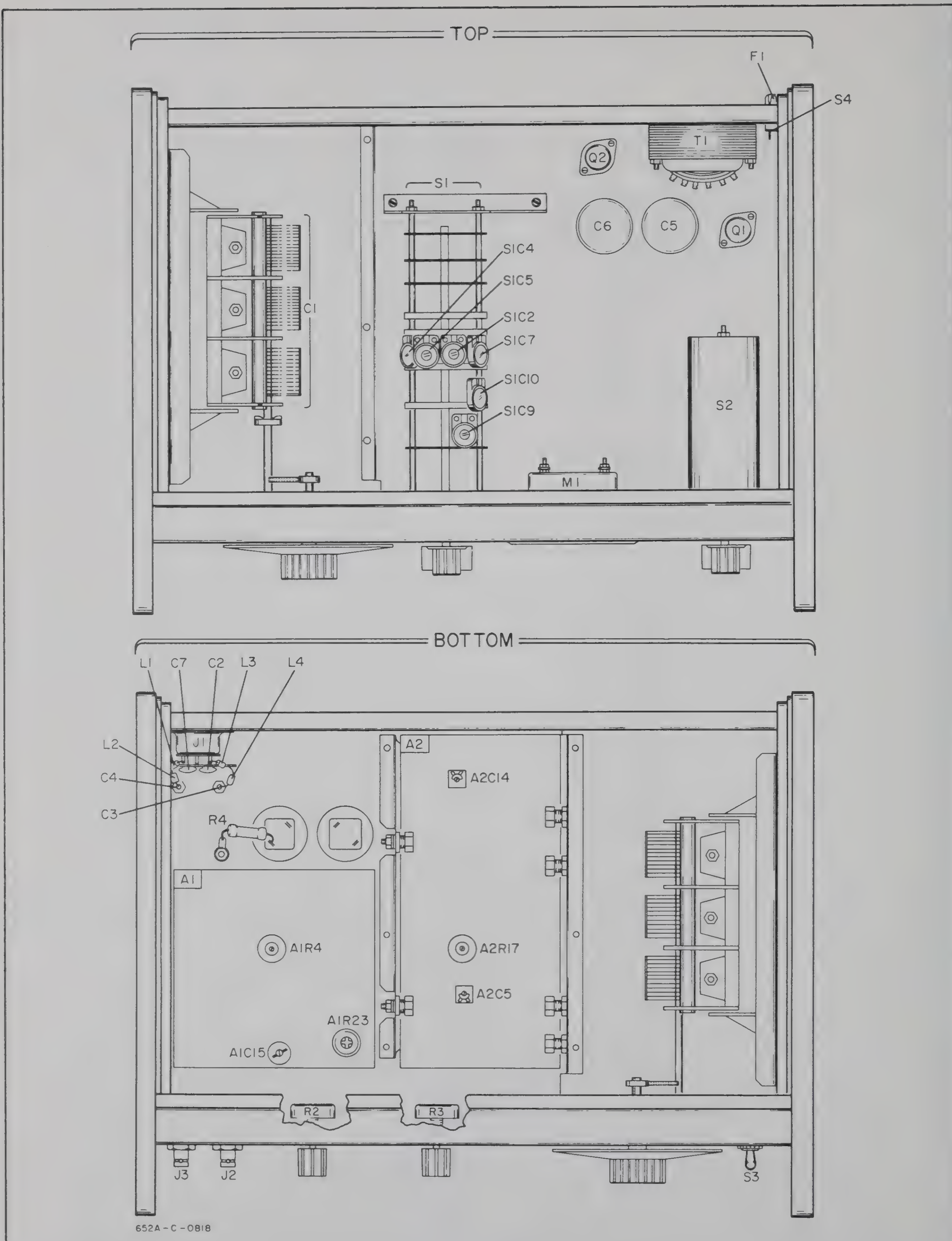



Figure 5-7. Location of Internal Adjustments

Table 5-7. Frequency Calibration Components

(Increasing the value of any of these components will decrease the frequency and change the A2TP2 voltage as indicated.)

| FREQUENCY RANGE | FREQUENCY DIAL READING = 10 | | FREQUENCY DIAL READING = 1 | |
|---|---|---|---|---|
| | Decreases A2TP2 Voltage | Increases A2TP2 Voltage | Increases A2TP2 Voltage | Decreases A2TP2 Voltage |
| X10 | --- | S1C14* | S1R1* | S1R14* |
| X100 | --- | --- | S1R3* | S1R16* |
| X1K | S1C2 | S1C7 | S1R5* | S1R18* |
| X10K | --- | S1C13* | S1R7* | S1R20* |
| X100K | S1C4 | S1C9 | S1R9* | S1R22* |
| X1M | S1C5 | S1C10 and A2C5 | S1R11* | S1R24* |

listed change both frequency and A2TP2 voltage in the same direction while the others change them in opposite directions. If the adjustments do not provide specified performance, then the procedure for changing padding resistors of Table 5-7 should be carefully followed.

NOTE

If 651B does not oscillate, turn FREQUENCY RANGE switch to X1K and adjust A2C5, S1C2 and S1C7 to start oscillations.

5-27. PRELIMINARY DISTORTION ADJUSTMENT.

a. Connect 651B to distortion analyzer as shown in Figure 5-5.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X1K |
| FREQUENCY dial . . . . . . | 1 |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE (COARSE and FINE) . | Extreme Clockwise |

c. Adjust A2R17 for minimum distortion which should be less than 1%.

5-28. FREQUENCY DIAL CALIBRATION.

a. Attach test lead with a 1 kΩ resistor in series to A2TP2; lead should be connected so that A2TP2 voltage can be monitored with bottom cover in place. Replace bottom cover. Care should be taken that test lead does not short to oscillator shield or instrument chassis.

b. Connect equipment as shown in Figure 5-8 and set 651B controls same as Paragraph 5-27b.

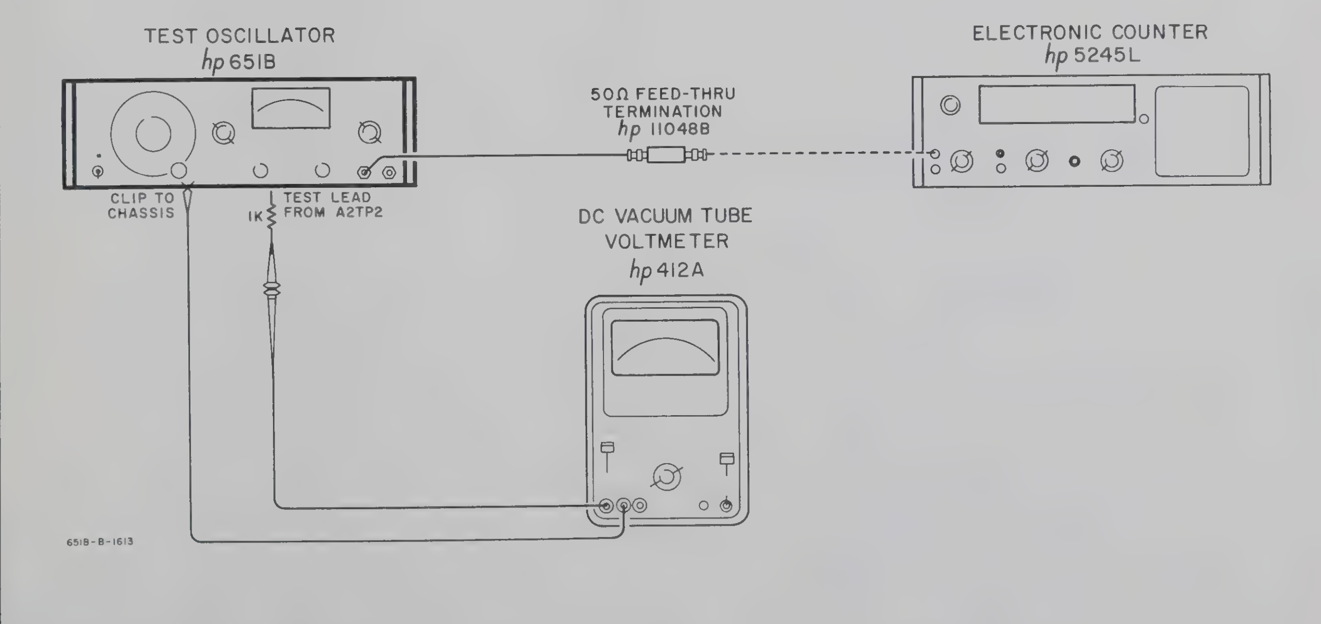



Figure 5-8. Frequency Calibration

c. Record A2TP2 voltage. This voltage should be between -0.32 V to -0.40 V in a calibrated instrument; however, at this point in the Calibration Procedure, it could be up to 200 mV outside this range. It is not necessary to correct the voltage as this will be done later in the procedure (Paragraph 5-31).

d. Set 651B FREQUENCY dial extreme counter-clockwise and adjust S1C2 and S1C7 alternately for counter indication of 10.2 kHz and A2TP2 voltage equal to voltage recorded in step c.

e. Turn 651B FREQUENCY dial to extreme clockwise position; counter should indicate frequency of 965 Hz to 970 Hz; if not, loosen tuner coupler (MP2, Figure 7-1) and slip tuner until specified frequency is obtained. (See CAUTION on Page 5-7.)

f. Set 651B FREQUENCY dial for a counter indication of 1 kHz. Dial should read 1; if not, carefully perform following procedure:

1) Remove FREQUENCY dial knob and loosen four dial retaining screws.

2) Slip FREQUENCY dial to read 1 with counter indication of 1 kHz.

3) Tighten retaining screws and replace knob.

g. Record A2TP2 voltage.

NOTE

This voltage will be the reference voltage used through Paragraphs 5-29 and 5-30; the Flatness specifications of the instrument depend on this voltage being maintained within the limits given in this Calibration Procedure.

h. Set 651B FREQUENCY dial to 10. Readjust S1C2 and S1C7 alternately until counter indicates frequency of 10 kHz and A2TP2 voltage equals voltage recorded in step 5-28g.

CAUTION

THE ADJUSTMENTS IN PARAGRAPHS 5-29 THROUGH 5-33 ARE HIGHLY CRITICAL. THE VALUES OF THE RANGE SWITCH RESISTORS WERE BRIDGED AT THE FACTORY FOR OPTIMUM PERFORMANCE, AND THEORETICALLY SHOULD NEVER HAVE TO BE CHANGED. DOUBLE-CHECK THE INSTRUMENT PERFORMANCE BEFORE CHANGING THE VALUES OF ANY OF THE RANGE SWITCH RESISTORS.

5-29. X100, X1K AND X10K RANGE FREQUENCY CALIBRATION.

a. Connect equipment as shown in Figure 5-8.

b. Check frequency tracking of FREQUENCY dial at 1, 5 and 10 on the X100, X1K and X10K ranges (see Table 5-8) while monitoring voltage at A2TP2. At 1 and 10 on the dial, A2TP2 voltage should be within ±20 mV of reference voltage noted in Paragraph 5-28g; over the entire range of the dial, A2TP2 voltage should not vary more than 40 mV.

Table 5-8. Frequency Dial Accuracy Check

| FREQUENCY DIAL | FREQUENCY RANGE | COUNTER INDICATION |
|---|---|---|
| | | (counter set to read period average) |
| 1 | X10 | 100 3 ms |
| 2 | X10 | 50 1.5 ms |
| 5 | X10 | 20 0.6 ms |
| 10 | X10 | 10 0.3 ms |
| 1 | X100 | 10 0.2 ms |
| 5 | X100 | 2 0.04 ms |
| 10 | X100 | 1 0.02 ms |
| | | (counter set to read frequency) |
| 1 | X1K | 1,000 20 Hz |
| 5 | X1K | 5,000 100 Hz |
| 10 | X1K | 10.0 0.2 kHz |
| 1 | X10K | 10.0 0.2 kHz |
| 5 | X10K | 50.0 1.0 kHz |
| 10 | X10K | 100.0 2.0 kHz |
| 1 | X100K | 100.0 2.0 kHz |
| 5 | X100K | 500.0 10 kHz |
| 10 | X100K | 1,000 20 kHz |
| 1 | X1M | 1,000 30 kHz |
| 5 | X1M | 5,000 150 kHz |
| 10 | X1M | 10,000 300 kHz |

c. On any of the three ranges, if frequency or A2TP2 voltage is not correct at 1 on dial, change the value of RANGE switch resistors (Table 5-7) for that range. (The two resistors should be changed simultaneously for the best results.)

NOTE

On the X1K RANGE only, if the RANGE switch resistors (S1R5* and S1R18*) are changed, it will be necessary to readjust S1C2 and S1C7 as outlined in Paragraph 5-28h. Then repeat steps 5-29b and c for the X100 and X10K ranges.

5-30. X10 RANGE FREQUENCY CALIBRATION.

a. Connect equipment as shown in Figure 5-8.

b. Set 651B FREQUENCY RANGE to X10. Check frequency as indicated on counter (see Table 5-8) at 1 and 10 positions of FREQUENCY dial.

c. If either frequency or A2TP2 voltage is not within tolerance, change values of S1R1* and S1R14* (Table 5-7) simultaneously to bring frequency within tolerance and maintain A2TP2 at required voltage (within +0.00 V, -0.05 V of reference voltage noted in Paragraph 5-28, step g).

NOTE

It may be necessary to split difference in frequency between the two ends of the dial.

d. Check frequency at the 2 and 5 positions of the dial. If not within tolerance (Table 5-8), repeat steps 5-30 b and c.

5-31. FEEDBACK VOLTAGE ADJUSTMENT.

a. Set 651B FREQUENCY RANGE to X1K and FREQUENCY dial to 1.

b. Remove 651B bottom cover and oscillator shield. Connect rms voltmeter with 1 kΩ resistor in series between A2TP1 and ground. Replace oscillator shield and bottom cover.

c. Rms voltmeter should indicate 110 ±10 mV rms. If A2TP1 voltage is not in tolerance, change value of A2R16* to bring voltage within specified limits (increasing value of A2R16* decreases A2TP1 voltage).

d. Record dc voltage on A2TP2, which should be 320 mV to 400 mV.

NOTE

If, in step c, A2R16* was changed, then the voltage at A2TP2 will also change; this will not affect the calibration which has been performed up to this point and it is not necessary to readjust the X10, X100, X1K or X10K ranges. The voltage recorded in Paragraph 5-31d now becomes the reference voltage for the remainder of the FREQUENCY CALIBRATION procedure.

5-32. X1M RANGE FREQUENCY CALIBRATION.

NOTE

The following adjustments are critical. For each adjustment, remove covers and make the adjustment; then replace covers before making frequency or voltage checks.

a. Connect the equipment as shown in Figure 5-8.

b. Set 651B FREQUENCY RANGE switch to X1M and FREQUENCY dial to 10. If 651B does not oscillate, adjust A2C5, S1C5 and S1C10.

c. Adjust A2C5 and S1C5 alternately for 10.15 MHz (1.5% high) as indicated on counter and for required voltage on A2TP2 (within ±0.02 V of reference voltage recorded in Paragraph 5-31d).

d. Set FREQUENCY dial to 5 and note frequency; if not within tolerance (Table 5-8), perform following:

1) Set dial to 10 and slightly change setting of S1C10. (Example: If frequency is low with 5 set on dial, adjust S1C10 to slightly lower frequency when dial is at 10; and vice-versa.)

2) Readjust A2C5 and S1C5 alternately for 10.15 MHz and required A2TP2 voltage (same as step c).

3) Set dial to 5 and note frequency; if still not within tolerance, repeat steps d-1, d-2, and d-3 as often as necessary until tolerances are met at both 5 and 10 positions of FREQUENCY dial.

e. Set FREQUENCY dial to 1. Check that frequency (Table 5-8) and A2TP2 voltage (same as in step c) are within required tolerances; if either is not correct, change value of RANGE switch resistors (Table 5-7) simultaneously until both frequency and voltage are within required limits.

NOTE

It may be necessary to set frequency about 1% high for the dial to track.

f. If RANGE switch resistors are changed in step e, it will be necessary to repeat steps c and d.

5-33. X100K RANGE FREQUENCY CALIBRATION.

NOTE

The following adjustments are critical. For each adjustment, remove cover and make the adjustment; then replace cover before making frequency or voltage checks.

a. Connect equipment as shown in Figure 5-8.

b. Set FREQUENCY RANGE to X100K and FREQUENCY dial to 10. Adjust S1C4 and S1C9 simultaneously for 1 MHz (see Table 5-8) as indicated on counter and for required A2TP2 voltage (within ±0.02 V of referenced voltage recorded in Paragraph 5-31d).

c. Set FREQUENCY dial to 1. Counter should indicate 100 kHz (see Table 5-8) and A2TP2 voltage should be same as in step b; if either is not within tolerance, change value of RANGE switch resistors (Table 5-7) simultaneously until both frequency and voltage are within required limits.

d. Repeat step b.

e. Set FREQUENCY dial to 5; frequency should be 500 kHz (see Table 5-8) as indicated on counter and A2TP2 voltage should be within required limits. If either is incorrect, repeat steps b, c, and d until both frequency and voltage are within specified tolerance. (Remove test lead and 1 kΩ resistor attached to A2TP2.)

5-34. 10 MHZ FLATNESS ADJUSTMENT.

a. Connect 651B to rms voltmeter as shown in Figure 5-2.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X1K |
| FREQUENCY dial . . . . . . | 10 |
| OUTPUT ATTENUATOR . . | 3.0 V |

c. Adjust 651B AMPLITUDE controls for 3.0 V as indicated on rms voltmeter. Do not readjust AMPLITUDE controls for remainder of this paragraph.

d. Connect equipment as shown in Figure 5-3. Adjust reference supply for null indication. Do not readjust reference supply once null is obtained.

e. Set 651B FREQUENCY RANGE to X1M. Sweep FREQUENCY dial slowly from 1 to 10. Null meter deviation from null should not exceed ±0.54 mV.

f. Adjust A2C14 to reduce any output peaking. If necessary, change value of A2C24* slightly.

5-35. OUTPUT ADJUSTMENTS.

5-36. WAVEFORM ADJUSTMENT.

a. Connect a 50 Ω load to 651B 50 Ω output terminal, and connect the output to an oscilloscope.

b. Set OUTPUT ATTENUATOR to 3.0 V, and turn AMPLITUDE controls fully counterclockwise.

c. Check 651B output, with and without load, on all frequencies. If spurious oscillations occur, change value of A2C21* until spurious oscillations are eliminated.

5-37. AMPLITUDE ADJUSTMENT.

a. Connect 651B to rms voltmeter, as shown in Figure 5-2.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X10 |
| FREQUENCY dial . . . . . . | 1 |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE . . . . . . . . | Fully clockwise |

c. Rms voltmeter should indicate at least 3.16 V. If maximum output is less than 3.16 V, slightly increase value of A2R24*.

5-38. MINIMUM DISTORTION ADJUSTMENT.

a. Connect 651B to distortion analyzer as shown in Figure 5-5.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X1K |
| FREQUENCY dial . . . . . . | 1 |
| OUTPUT ATTENUATOR . . | 3.0 V |
| AMPLITUDE . . . . . . . . | Fully clockwise |

c. Adjust A2R17 for minimum distortion as indicated on distortion analyzer. Distortion should be less than 1% (40 dB down).

NOTE

Distortion will be typically 50 dB down.

5-39. OUTPUT MONITOR CALIBRATION.

NOTE

The following adjustments are critical. Final voltage measurements must be made with all instrument covers in place.

a. Connect 651B to rms voltmeter as shown in Figure 5-2.

b. Set 651B controls as follows:

| | |
|---|---|
| FREQUENCY RANGE . . . . | X100 |
| FREQUENCY dial . . . . . . | 4 |
| OUTPUT AMPLITUDE . . . | 3.0 V |

c. Set AMPLITUDE controls for a 3.0 V indication on rms voltmeter.

d. Adjust A1R23 for a 3.0 V indication on 651B monitor. If A1R23 does not have sufficient range to properly calibrate monitor, change value of A1R22*. (Increasing A1R22* increases monitor indication and vice-versa.)

e. Set 651B FREQUENCY RANGE to X1M, and FREQUENCY dial to 10.

f. Set 651B AMPLITUDE controls for a 3.0 V indication on rms voltmeter.

g. Making allowance for any error of the rms voltmeter at 10 MHz, adjust A1C15 for a 3.0 V indication on 651B monitor.

NOTE

If rms voltmeter error at 10 MHz is not known, follow this alternative procedure.

h. Perform steps a through d.

i. Connect equipment as shown in Figure 5-3 and adjust reference supply for null indication on null meter.

j. Set 651B FREQUENCY RANGE to X1M and FREQUENCY dial to 10.

k. Adjust 651B AMPLITUDE controls for null indication on null meter. Do not readjust reference supply.

l. Adjust A1C15 for 3.0 V indication on 651B monitor.

5-40. AFTER CALIBRATION.

5-41. After completing the ADJUSTMENT AND CALIBRATION PROCEDURE (Paragraphs 5-20 through 5-39), repeat PERFORMANCE CHECKS (Paragraphs 5-7 through 5-19) to assure that the 651B is within specifications listed in Table 1-1.

## 5-42. TROUBLESHOOTING PROCEDURE.

5-43. This section contains information and procedures designed to aid in the process of isolating malfunctions. Troubleshooting should be undertaken only after it has been determined that the malfunction cannot be corrected by performing the adjustment and calibration procedures.

5-44. When a malfunction occurs, remove power from the 651B, and visually inspect for loose or broken wires, connectors, or components. Also, an investigation should be made to ensure that the trouble is not the result of conditions external to the instrument.

5-45. The Troubleshooting Tree in Figure 5-9 illustrates a systematic method of elimination used to locate a faulty circuit or component. The tree does not include specific troubles and problems; it presents a list of key points to be checked for normal circuit indications or conditions, which can be used to eliminate the properly operating circuits from the troubleshooting path. The checks outlined in the troubleshooting tree were not devised to measure all circuit parameters, but to localize the malfunction. Therefore, additional checks and measurements will probably be required to completely isolate the faulty component.

5-46. To use the troubleshooting tree, decide if (1) is true or false, and proceed to the next step along the pertinent branch of the tree. In some cases, there are two or more branches for a given indication, meaning that either one or all the branches could lead to the malfunction. Additional information for use with the troubleshooting tree is given in Paragraph 5-47. Refer to the block diagram in Figure 6-1, and the schematics of Figures 6-2 and 6-3, when using the troubleshooting tree.

5-47. TROUBLESHOOTING INFORMATION.

5-48. This section provides additional information for each particular step of the troubleshooting tree.

(1) Check the output at both output connectors, and ensure that it is undistorted and within specifications, over the entire frequency range of the instrument.

(2) When the 651B output voltage is 3, the normal dc voltage applied at A1 pin 16 is approximately +2.7 V. The voltage at A1 pin 17 should be about 0.14 V less than that at A1 pin 16; if not, M1 is probably faulty.

(3) If the oscillator circuit is operating properly, the signal at A2 pin 5 will be a sine wave of 10 V to 12 V peak-to-peak. This voltage should remain constant, regardless of the amplitude or frequency setting of the instrument.

(4) Check fuse F1 if there is no output and the line indicator lamp does not light; also ensure that the 115/230 V switch, S4, is in the correct position.

(5) Disconnect M1 from the circuit, and apply a current of 1.5 mA, to check for full scale deflection. Decrease the current, and the pointer deflection of M1 should decrease proportionally.

(6) When the 651B output voltage is 3, the ac signal applied to the rectifier from the collector of A1Q9 is approximately 0.75 Vac.

(7) Check the rectifier diodes A1CR8 through A1CR10, and capacitors A1C12 and A1C13. Also check A1C11 and A1CR11.

(8) Check the dc voltages on A1Q8 and A1Q9 at the points listed below; also check A1C11 and A1CR10.

| | |
|---|---|
| Emitter A1Q8 . . . . . . | +1.8 V |
| Collector A1Q9 . . . . . | +2.5 V |
| Base A1Q9 . . . . . . . | -9.8 V |
| Emitter A1Q9 . . . . . . | -10.5 V |

(9) The normal signal at A2 pin 20 will be a sine wave of about 16 V peak-to-peak, when the 651B output is 3 V.

(10) A2TP2 should have a dc voltage from -0.3 to -0.4 V. If the voltage is positive, C1 is probably shorted, or the peak detector is bad. If the voltage is negative, but out of tolerance, check A2Q1 through A2Q6.

(11) If there is no positive or negative output from the power supply, isolate it from external circuits by disconnecting A2 pins 1, 2, 6 and 7. If the power supply outputs return to normal, the malfunction is in one of the external circuits, causing it to load the power supply.

(12) Check S2R1 through S2R12 if there is no output at either the 50 ohm or 600 ohm connector. Check S2R13 if the output is missing only at the 600 ohm connector.

(13) Check A2Q8 through A2Q12, and A2C19. If A2C19 becomes shorted, A2Q11 and A2Q12 will be destroyed.

(14) If the oscillator circuit is functioning normally, but no signal is present at A2 pin 5, coupling capacitor A2C12 is probably bad.

(15) If the instrument is malfunctioning on all frequency ranges, check A2Q2 through A2Q6, and A2CR1 through A2CR4. (If either A2Q2 or A2Q3 is replaced, repeat the Frequency Calibration Procedure in Paragraphs 5-26 through 5-33. A2Q5 and A2Q6 should be replaced as a pair, if either goes bad.) If the instrument malfunctions only on the lower four ranges, A2Q1 is probably bad.

(16) Check A2Q7, A2CR5, A2CR8 and A2CR9. If these components are good, check A2CR6 and A2CR7.

(17) If the 651B output is within specifications on some frequency ranges, but is not on others, check the S1 components for the inoperative ranges. If the output is unstable or distorted through portions of all frequency ranges, check tuning capacitor C1.

(18) Check the power supply connections to external circuits, and check the resistors in series with the connections (A2R13, A2R26, A2R37, and A2R44).

(19) If only the negative half of the power supply output is bad, check Q2, A1Q5, A1Q6, A1CR3, and A1CR4.

(20) If both the positive and negative power supply outputs are bad, check for 43 V ac at A1 pin 5, and 40 V ac at A1 pin 7. If these voltages are not correct, the malfunction is probably either T1 or one of the line filter components.

(21) The negative power supply output is referenced to the positive supply; consequently, if both outputs are incorrect, the malfunction is probably in the positive supply. Check the components in the positive supply - Q1, A1Q2, A1Q3, A1CR1 and A1CR2.

(22) Check T1 and the line filter components, L1 through L4, C2, C3, C4, and C7.

5-49. SERVICING ETCHED CIRCUIT BOARDS.

5-50. The Model 651B contains two plated-through, double-sided, etched circuit boards. When working on these boards, observe the following rules to prevent damage to the circuit board or components:

a. Use a low-heat (25 to 50 watts) soldering iron with small tip.

b. To remove a component, clip a heat sink (long nose pliers, commercial heat sink tweezers, etc.) on the component lead as close to the component as possible. Place the soldering iron directly on the component lead, and pull up on the lead. If a component is obviously damaged or faulty, clip the leads close to the component, and remove the leads from the board.

**CAUTION**

EXCESSIVE OR PROLONGED HEAT CAN LIFT THE CIRCUIT FOIL FROM THE BOARD OR CAUSE DAMAGE TO COMPONENTS.

c. Clean the component lead holes by heating the solder in the hole, quickly removing the soldering iron, and inserting a pointed, non-metallic object such as a toothpick.

d. To mount a new component, shape the leads and insert them in the holes. Clip a heat sink on the component, heat with the soldering iron, and add solder as necessary to obtain a good electrical connection.

5-51. SERVICING ROTARY SWITCHES.

5-52. The Model 651B contains two rotary type switches: FREQUENCY RANGE and OUTPUT ATTENUATOR. When working on these switches, observe the following rules:

a. Use a low heat (25 to 50 watts) soldering iron with a small tip.

b. When replacing components, attempt to dress them as nearly to their original alignment as possible.

c. Clean excessive flux from the connection and adjoining area.

d. After cleaning the switch, apply a light coat of lubriplate to the switch detent balls. DO NOT apply lubricant to switch contacts or allow lubricant to contaminate components.

5-53. SERVICING TUNER ASSEMBLY.

5-54. When replacing the tuning capacitor, C1, make certain that the tuner coupler and the frequency dial shaft are aligned to prevent binding of the FREQUENCY dial or VERNIER control. If necessary, remove the frequency dial knob, frequency dial, and loosen the tuner drive assembly (casting and spur gears) retaining screws; then align tuner coupler and frequency dial shaft. Tighten retaining screws after tuner coupler and dial shaft are aligned.

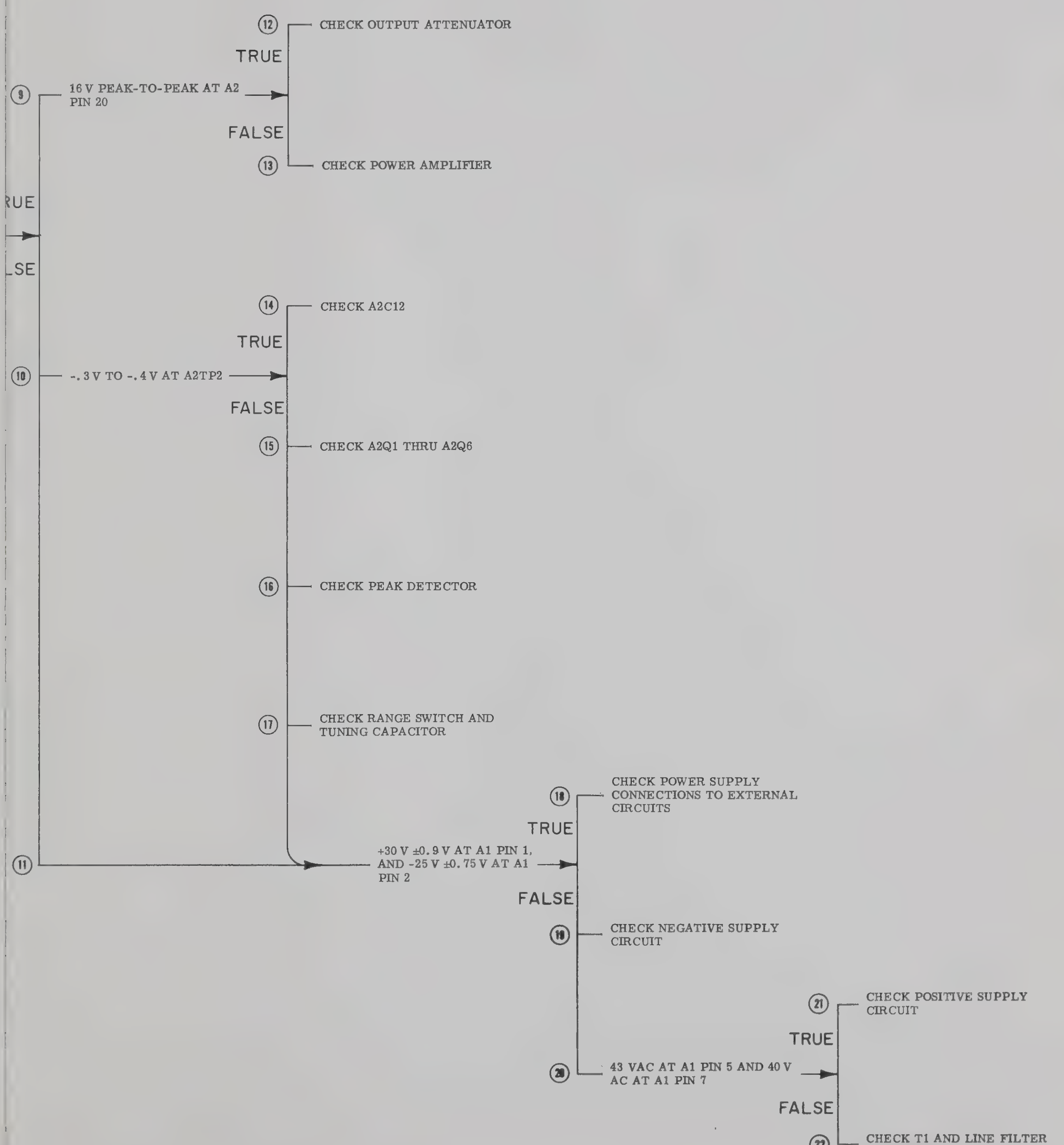



Figure 5-9. Troubleshooting Tree

(17) If the 651B output is within specifications on some frequency ranges, but is not on others, check the S1 components for the inoperative ranges. If the output is unstable or distorted through portions of all frequency ranges, check tuning capacitor C1.

(18) Check the power supply connections to external circuits, and check the resistors in series with the connections (A2R13, A2R26, A2R37, and A2R44).

(19) If only the negative half of the power supply output is bad, check Q2, A1Q5, A1Q6, A1CR3, and A1CR4.

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(21) The negative power supply output is referenced to the positive supply; consequently, if both outputs are incorrect, the malfunction is probably in the positive supply. Check the components in the positive supply - Q1, A1Q2, A1Q3, A1CR1 and A1CR2.

(22) Check T1 and the line filter components, L1 through L4, C2, C3, C4, and C7.

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a. Use a low-heat (25 to 50 watts) soldering iron with small tip.

b. To remove a component, clip a heat sink (long nose pliers, commercial heat sink tweezers, etc.) on the component lead as close to the component as possible. Place the soldering iron directly on the component lead, and pull up on the lead. If a component is obviously damaged or faulty, clip the leads close to the component, and remove the leads from the board.

**CAUTION**

EXCESSIVE OR PROLONGED HEAT CAN LIFT THE CIRCUIT FOIL FROM THE BOARD OR CAUSE DAMAGE TO COMPONENTS.

c. Clean the component lead holes by heating the solder in the hole, quickly removing the soldering iron, and inserting a pointed, non-metallic object such as a toothpick.

d. To mount a new component, shape the leads and insert them in the holes. Clip a heat sink on the component, heat with the soldering iron, and add solder as necessary to obtain a good electrical connection.

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a. Use a low heat (25 to 50 watts) soldering iron with a small tip.

b. When replacing components, attempt to dress them as nearly to their original alignment as possible.

c. Clean excessive flux from the connection and adjoining area.

d. After cleaning the switch, apply a light coat of lubriplate to the switch detent balls. DO NOT apply lubricant to switch contacts or allow lubricant to contaminate components.

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5-54. When replacing the tuning capacitor, C1, make certain that the tuner coupler and the frequency dial shaft are aligned to prevent binding of the FREQUENCY dial or VERNIER control. If necessary, remove the frequency dial knob, frequency dial, and loosen the tuner drive assembly (casting and spur gears) retaining screws; then align tuner coupler and frequency dial shaft. Tighten retaining screws after tuner coupler and dial shaft are aligned.

## NOTE

When using the troubleshooting tree, set the 651B controls as follows, unless stated otherwise for a particular step:

| | |
|---|---|
| FREQUENCY RANGE | X1K |
| FREQUENCY dial | 5 |
| OUTPUT ATTENUATOR | 3.0 V |
| AMPLITUDE | Adjust for an RMS voltmeter indication of 3 V (use test setup shown in Figure 5-2) |

A tolerance of ±10% should be allowed for all voltages given in the troubleshooting tree, unless stated otherwise.

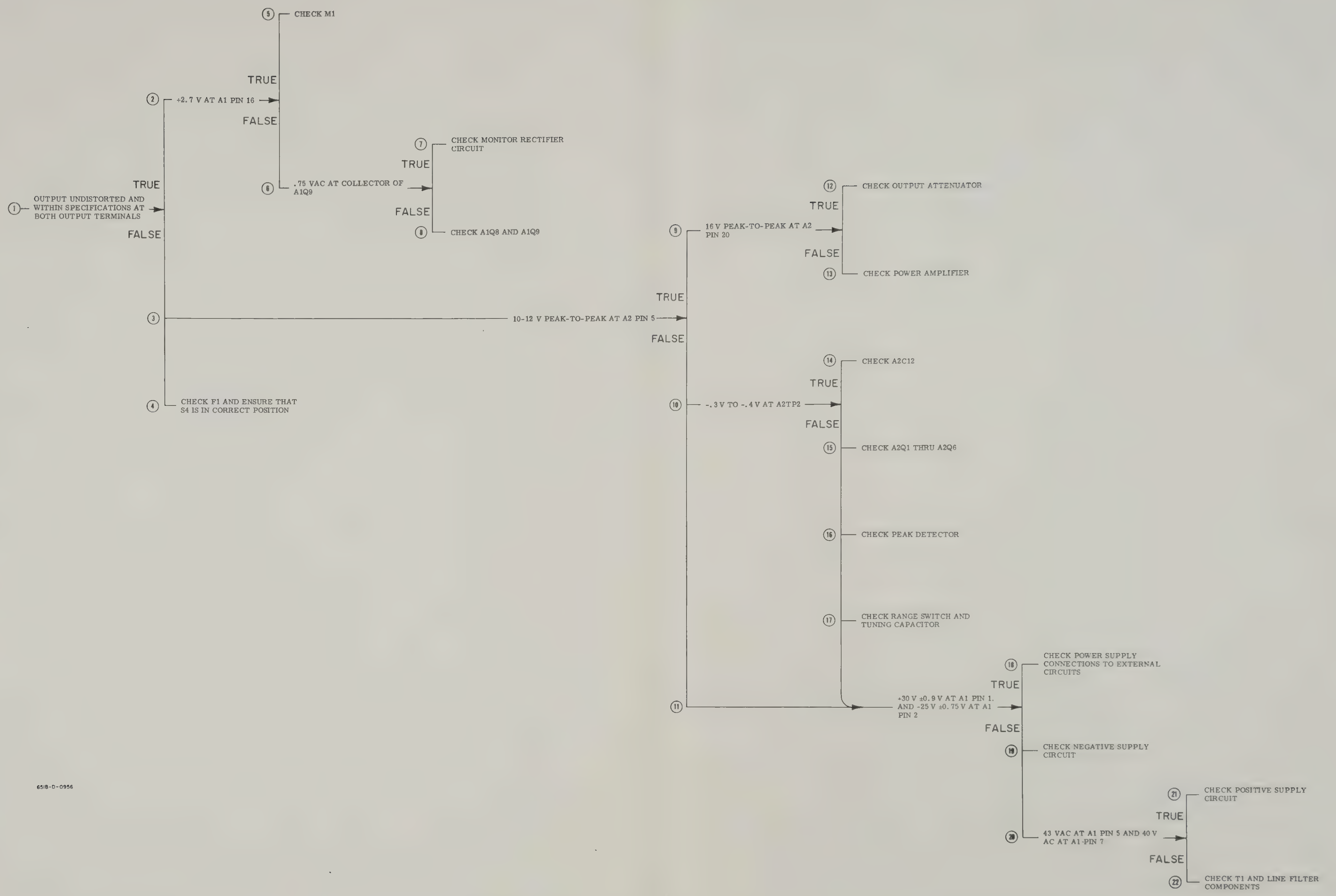



Figure 5-9. Troubleshooting Tree

## PERFORMANCE CHECK TEST CARD

Hewlett-Packard Model 651B
Test Oscillator
Serial No. ________________

Tests Performed by ______________________________
Date ______________________________

| 5-7. FREQUENCY RANGE: | | Frequency (Period) | | |
|---|---|---|---|---|
| Freq. Range | Dial Settings | Min. | | Max. |
| X10 | Clockwise | (100 ms) | ______ | --- |
| X1M | Counterclockwise | 10 MHz | ______ | --- |

| 5-8. DIAL ACCURACY: | | Frequency (Period) | | |
|---|---|---|---|---|
| Freq. Range | Dial Settings | Min. | | Max. |
| X10 | 1 | (97 ms) | ______ | (103 ms) |
| X10 | 5 | (19.4 ms) | ______ | (20.6 ms) |
| X10 | 10 | (9.7 ms) | ______ | (10.3 ms) |
| X100 | 1 | (9.8 ms) | ______ | (10.2 ms) |
| X100 | 5 | (1.96 ms) | ______ | (2.04 ms) |
| X100 | 10 | (0.98 ms) | ______ | (1.02 ms) |
| X1K | 1 | 0.98 kHz | ______ | 1.02 kHz |
| X1K | 5 | 4.9 kHz | ______ | 5.0 kHz |
| X1K | 10 | 9.8 kHz | ______ | 10.2 kHz |
| X10K | 1 | 9.8 kHz | ______ | 10.2 kHz |
| X10K | 5 | 49.0 kHz | ______ | 51.0 kHz |
| X10K | 10 | 98.0 kHz | ______ | 102.0 kHz |
| X100K | 1 | 98.0 kHz | ______ | 102.0 kHz |
| X100K | 5 | 490.0 kHz | ______ | 510.0 kHz |
| X100K | 10 | 980.0 kHz | ______ | 1020.0 kHz |
| X1M | 1 | 0.97 MHz | ______ | 1.03 MHz |
| X1M | 5 | 4.85 MHz | ______ | 5.15 MHz |
| X1M | 10 | 9.70 MHz | ______ | 10.30 MHz |

| 5-9. OUTPUT: | Min. | | Max. |
|---|---|---|---|
| Maximum Voltage - 50 Ω output | 3.16 V | ______ | --- |
| 600 Ω output | 3.16 V | ______ | --- |
| Flatness (Amplitude not readjusted to a reference on the output monitor) | | | |
| Freq. Range | | | |
| 100 Hz to 1 MHz | --- | ______ | ± 2% |
| 10 Hz to 1 MHz | --- | ______ | ± 3% |
| 10 Hz to 10 MHz | --- | ______ | ± 4% |
| Flatness (Amplitude readjusted to a reference on the output monitor) | | | |
| Freq. Range | | | |
| 10 Hz to 20 Hz | --- | ______ | 2% |
| 20 Hz to 4 MHz | --- | ______ | 1% |
| 4 MHz to 10 MHz | --- | ______ | 2% |

| 5-13. OUTPUT MONITOR ACCURACY: | Min. | | Max. |
|---|---|---|---|
| | 2.94 V | ______ | 3.06 V |

| 5-14. ATTENUATOR: | 651B Attenuator | RMS Voltmeter | Frequency 1 kHz | Frequency 10 MHz |
|---|---|---|---|---|
| | +20 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | +10 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | 0 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -10 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -20 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -30 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -40 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -50 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -60 dB | 8.91 mV to 9.09 mV | ______ | ______ |
| | -70 dB | 8.82 mV to 9.18 mV | ______ | ______ |

| 5-15. AMPLITUDE CONTROL: | RMS Voltmeter | |
|---|---|---|
| | >-20 dB | ______ |

| 5-16. DISTORTION: Freq. Range | Dial Setting | Distortion Meter | |
|---|---|---|---|
| X10 | 1 | <1% | ______ |
| X100 | 1 | <1% | ______ |
| X1K | 1 | <1% | ______ |
| X10K | 1 | <1% | ______ |
| X100K | 1 | <1% | ______ |
| X100K | 5 | <1% | ______ |
| X1M | 2 | <1% | ______ |
| X1M | 5 | <2% | ______ |
| X1M | 10 | <4% | ______ |

| 5-17. AMPLITUDE STABILITY: | RMS Voltmeter | |
|---|---|---|
| | >-66 dB | ______ |

| 5-18. AMPLITUDE STABILITY: | 2% per month ($20^{o}C$ - $30^{o}C$) | ______ |
|---|---|---|

| 5-19. OUTPUT IMPEDANCE: | Min. | | Max. |
|---|---|---|---|
| 50 Ω output | 45 Ω | ______ | 55 Ω |
| 600 Ω output | 540 Ω | ______ | 660 Ω |

# SECTION VI
# CIRCUIT DIAGRAMS

## 6-1. INTRODUCTION.

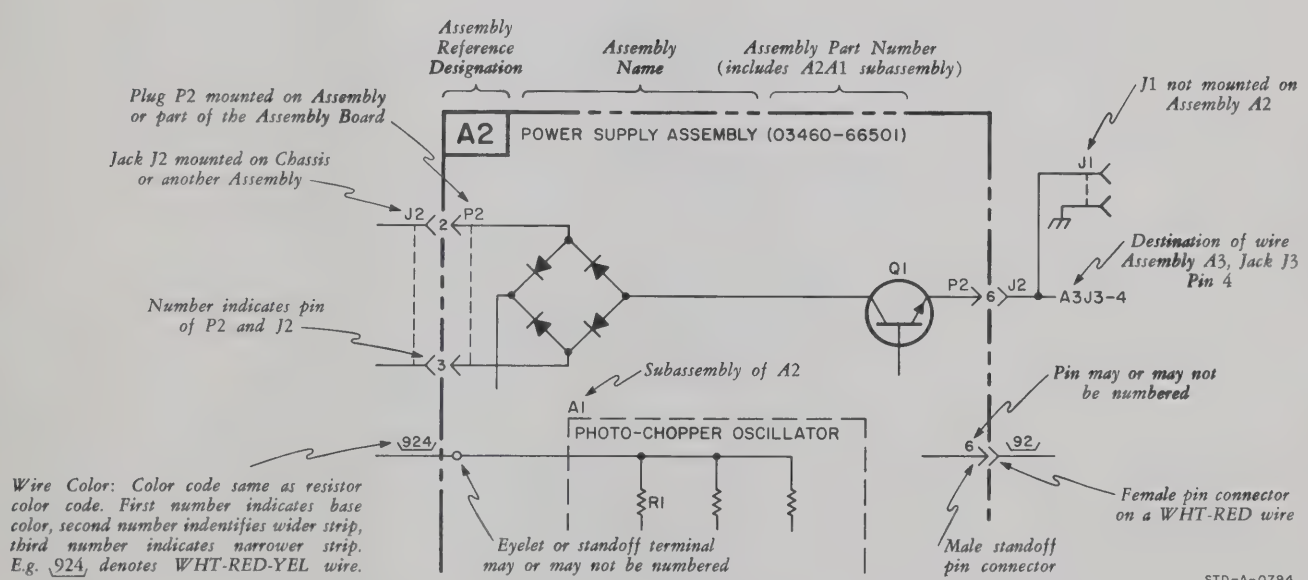
6-2. This section contains the circuit diagrams necessary for operation and maintenance of the Model 651B. Figure 6-1 is a block diagram which shows the overall relationship between the basic circuits of the instrument. Figures 6-2 and 6-3 contain the detailed schematic diagrams as well as component location drawings of each printed circuit board and the two rotary switches.

6-3. An explanation of terms and symbols used as reference designators is given below.

### REFERENCE DESIGNATIONS

PARTIAL REFERENCE DESIGNATIONS ARE SHOWN: PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.

| ASSEMBLY | SUBASSEMBLY | COMPONENT | COMPLETE DESIGNATION |
|---|---|---|---|
| A2 | NONE | Q1 | A2Q1 |
| A2 | A1 | R1 | A2A1R1 |
| NONE | NONE | J1 | J1 |



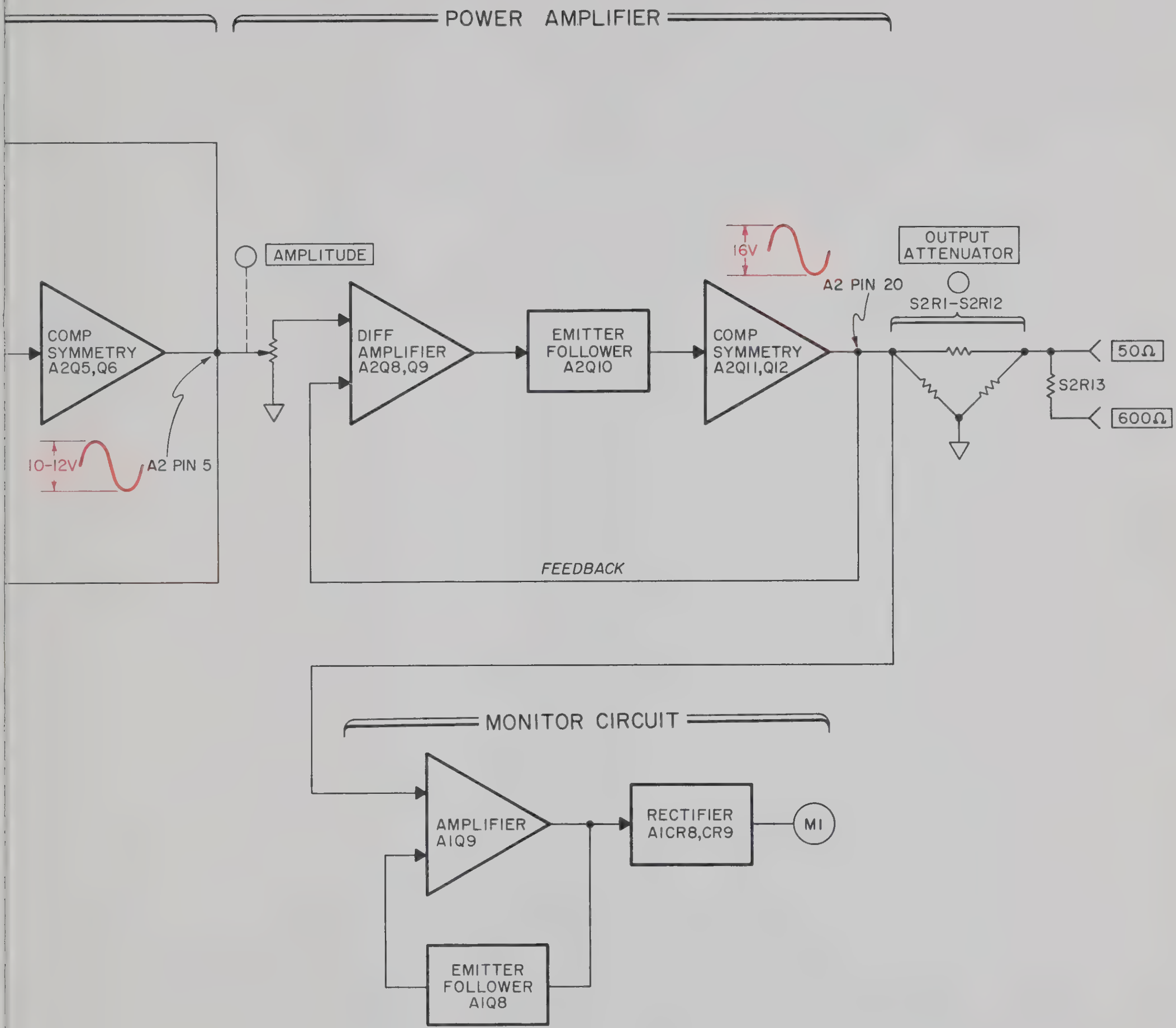



Figure 6-1. Block Diagram

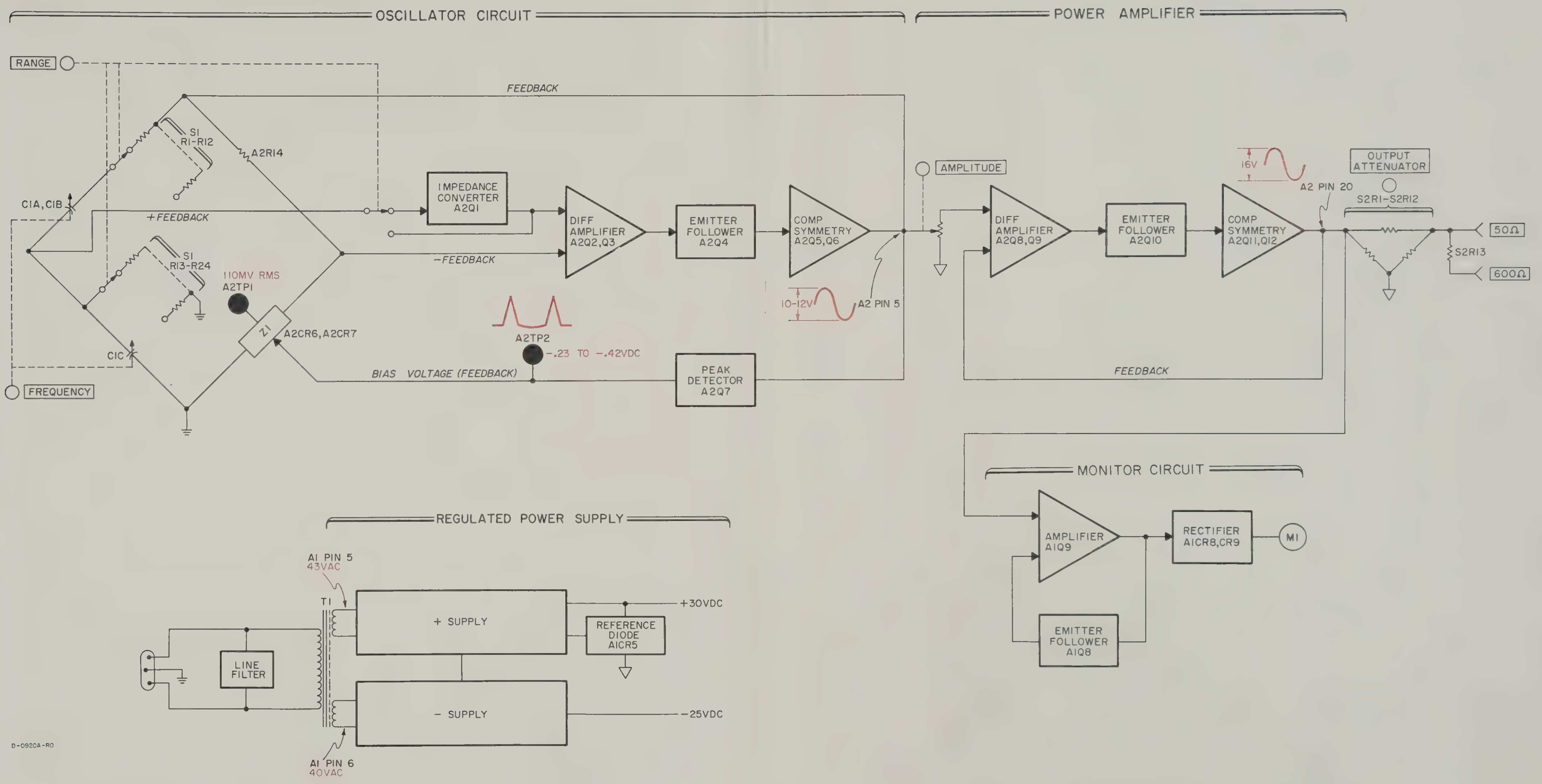
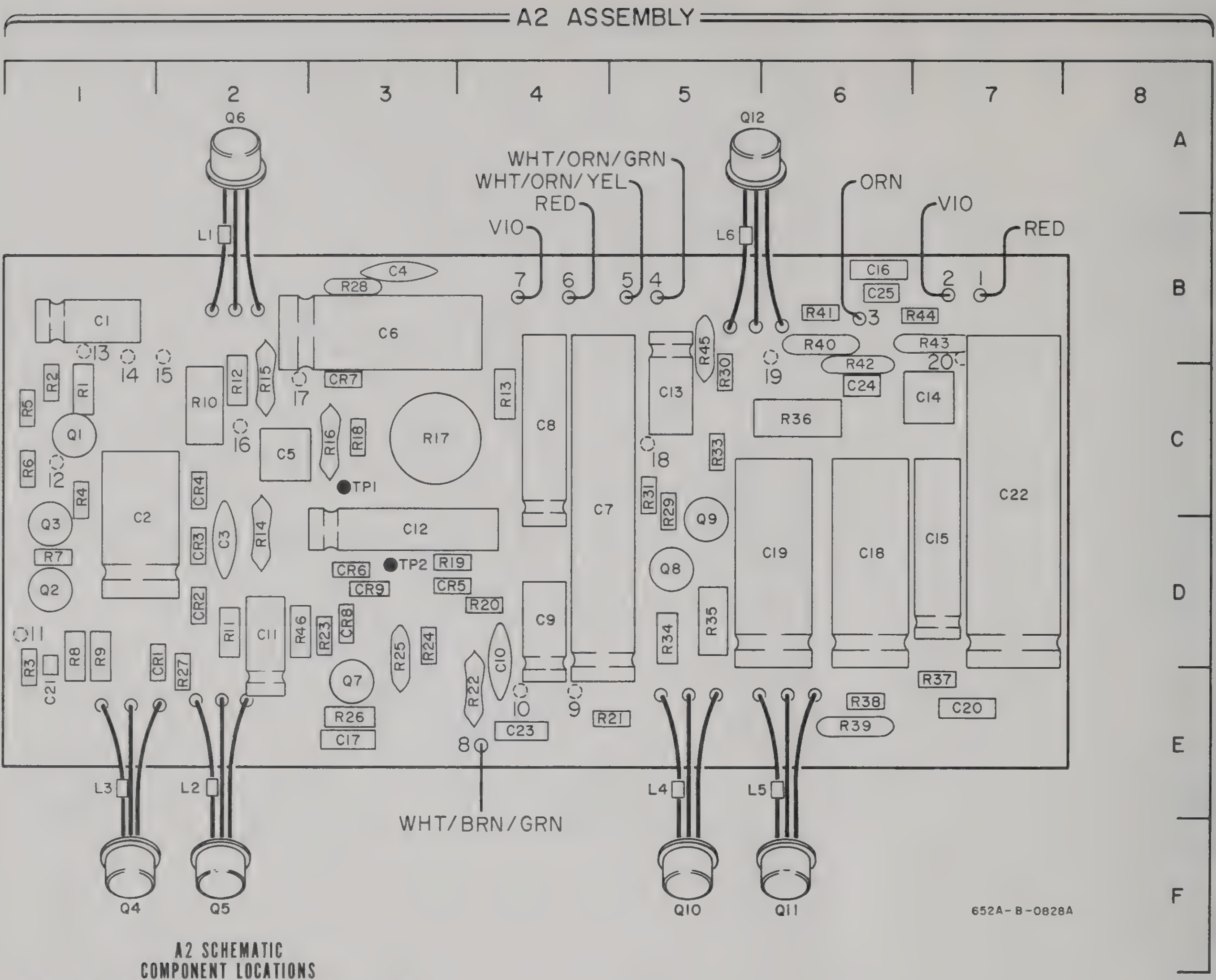



Figure 6-1. Block Diagram



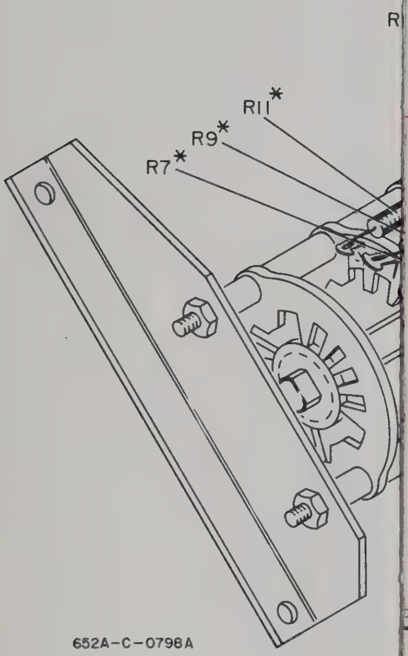

**A2 SCHEMATIC COMPONENT LOCATIONS**

| | C | CR | L | Q | R | | R |
|---|---|---|---|---|---|---|---|
| 1 | H14 | E15 | G16 | F12 | F11 | 26 | C18 |
| 2 | D13 | F15 | E16 | F14 | G12 | 27 | D16 |
| 3 | F16 | F15 | D15 | G14 | J15 | 28 | H16 |
| 4 | J16 | G15 | D21 | E15 | G14 | 29 | F20 |
| 5 | F8 | F17 | E22 | F16 | H14 | 30 | H19 |
| 6 | F7 | H8 | G22 | G16 | H14 | 31 | C20 |
| 7 | J8 | H7 | | F18 | F14 | 32 | --- |
| 8 | J9 | F18 | | F20 | D14 | 33 | G20 |
| 9 | J7 | F17 | | G20 | D14 | 34 | D20 |
| 10 | J8 | | | E21 | H15 | 35 | F21 |
| 11 | G17 | | | F22 | F16 | 36 | H21 |
| 12 | C16 | | | G22 | G16 | 37 | C23 |
| 13 | C17 | | | | J12 | 38 | F22 |
| 14 | J22 | | | | D7 | 39 | F23 |
| 15 | J23 | | | | E7 | 40 | G23 |
| 16 | H19 | | | | F7 | 41 | G23 |
| 17 | D19 | | | | G7 | 42 | G23 |
| 18 | G22 | | | | G7 | 43 | J23 |
| 19 | F22 | | | | H10 | 44 | H23 |
| 20 | D23 | | | | H8 | 45 | H22 |
| 21 | D14 | | | | J8 | 46 | E18 |
| 22 | F23 | | | | H17 | | |
| 23 | J17 | | | | G17 | | |
| 24 | G23 | | | | G17 | | |
| 25 | G24 | | | | H17 | | |

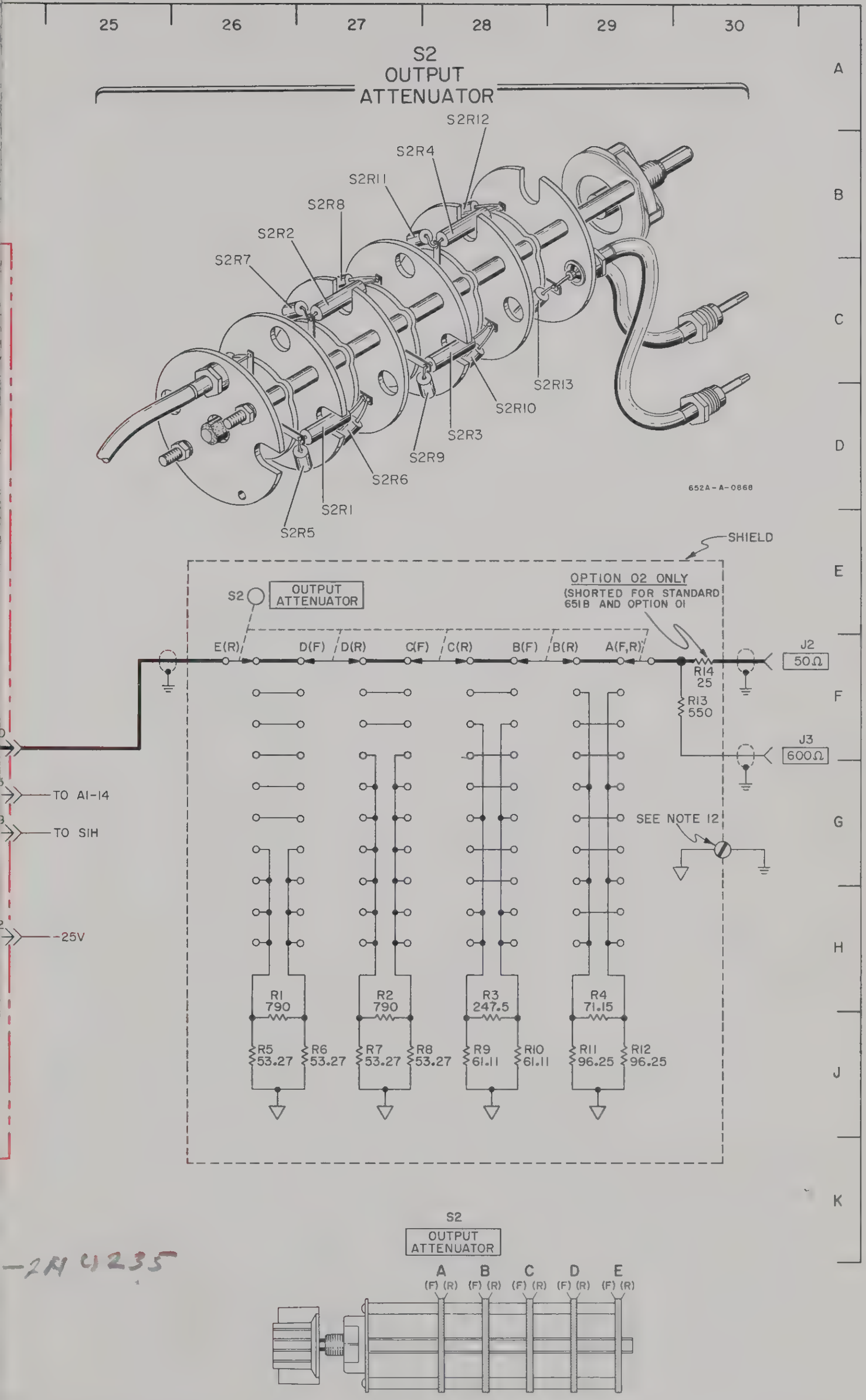
**A2 ASSEMBLY WIRE COLORS (BOTTOM)**

| PIN NO. | WIRE COLOR |
|---|---|
| 9 | WHITE |
| 10 | BLACK |
| 11 | WHT/ORN |
| 12 | BLACK |
| 13 | ORANGE |
| 14 | WHT/YEL |
| 15 | RED |
| 16 | WHT/YEL |
| 17 | BLACK |
| 18 | WHT/BLK |
| 19 | BLUE |
| 20 | |

p/o Figure 6-2. Oscillator Circuit




652A-C-0798A

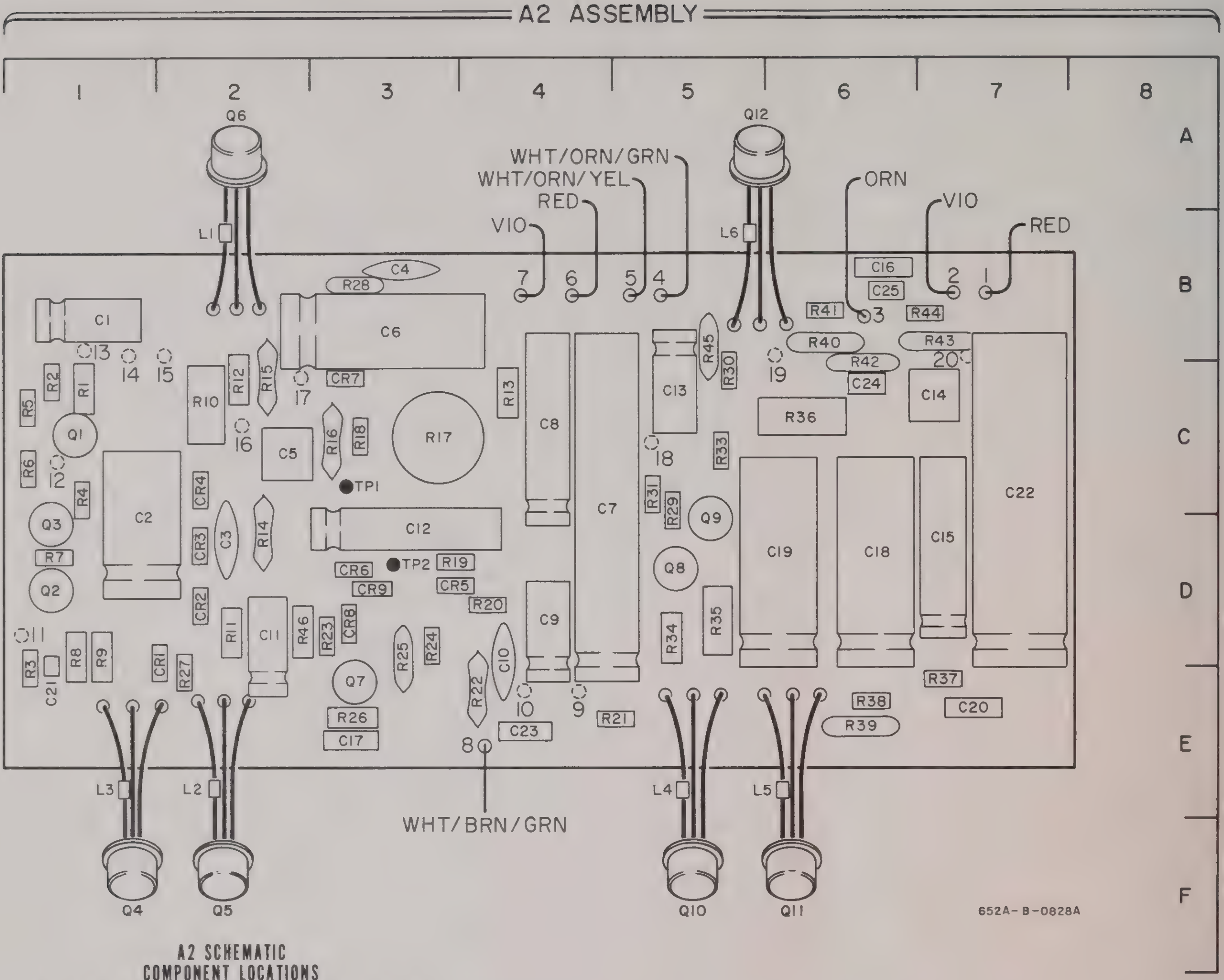



-2H 4235

NOTES

1. PARTIAL REFERENCE DESIGNATIONS A
   OR SUBASSEMBLY DESIGNATION(S) OR
2. COMPONENT VALUES ARE SHOWN AS F
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
3. DENOTES
4. DENOTES
5. DENOTES
6. DENOTES FRONT PANEL MAR
7. DENOTES SCREWDRIVER ADJ
8. DENOTES FRONT PANEL CONTRO
9. DENOTES CHASSIS GROUND.
10. DENOTES CIRCUIT GROUND.
11. * AVERAGE VALUE SHOWN, OPTIMU
12. DENOTES GROUND CONNECTION M
    SCREWS IN PLACE.
13. DENOTES SHIELDING BEAD.
14. REFERENCE DESIGNATORS PRINTED I
    CHANGES (SEE APPENDIX C).

Figure 6-2. Oscillator Circuit

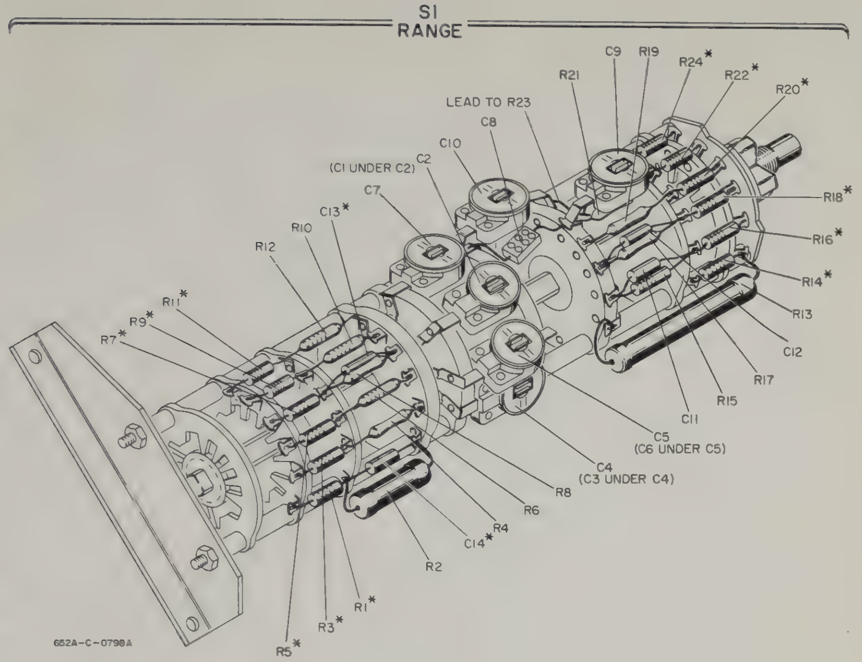



**A2 SCHEMATIC COMPONENT LOCATIONS**

| | C | CR | L | Q | R | | R |
|---|---|---|---|---|---|---|---|
| 1 | H14 | E15 | G16 | F12 | F11 | 26 | C18 |
| 2 | D13 | F15 | E16 | F14 | G12 | 27 | D16 |
| 3 | F16 | F15 | D15 | G14 | J15 | 28 | H16 |
| 4 | J16 | G15 | D21 | E15 | G14 | 29 | F20 |
| 5 | F8 | F17 | E22 | F16 | H14 | 30 | H19 |
| 6 | F7 | H8 | G22 | G16 | H14 | 31 | C20 |
| 7 | J8 | H7 | | F18 | F14 | 32 | --- |
| 8 | J9 | F18 | | F20 | D14 | 33 | G20 |
| 9 | J7 | F17 | | G20 | D14 | 34 | D20 |
| 10 | J8 | | | E21 | H15 | 35 | F21 |
| 11 | G17 | | | F22 | F16 | 36 | H21 |
| 12 | C16 | | | G22 | G16 | 37 | C23 |
| 13 | C17 | | | | J12 | 38 | F22 |
| 14 | J22 | | | | D7 | 39 | F23 |
| 15 | J23 | | | | E7 | 40 | G23 |
| 16 | H19 | | | | F7 | 41 | G23 |
| 17 | D19 | | | | G7 | 42 | G23 |
| 18 | G22 | | | | G7 | 43 | J23 |
| 19 | F22 | | | | H10 | 44 | H23 |
| 20 | D23 | | | | H8 | 45 | H22 |
| 21 | D14 | | | | J8 | 46 | E18 |
| 22 | F23 | | | | H17 | | |
| 23 | J17 | | | | G17 | | |
| 24 | G23 | | | | G17 | | |
| 25 | G24 | | | | H17 | | |

**A2 ASSEMBLY WIRE COLORS (BOTTOM)**

| PIN NO. | WIRE COLOR |
|---|---|
| 9 | WHITE |
| 10 | BLACK |
| 11 | WHT/ORN |
| 12 | BLACK |
| 13 | ORANGE |
| 14 | WHT/YEL |
| 15 | RED |
| 16 | WHT/YEL |
| 17 | BLACK |
| 18 | WHT/BLK |
| 19 | BLUE |
| 20 | |

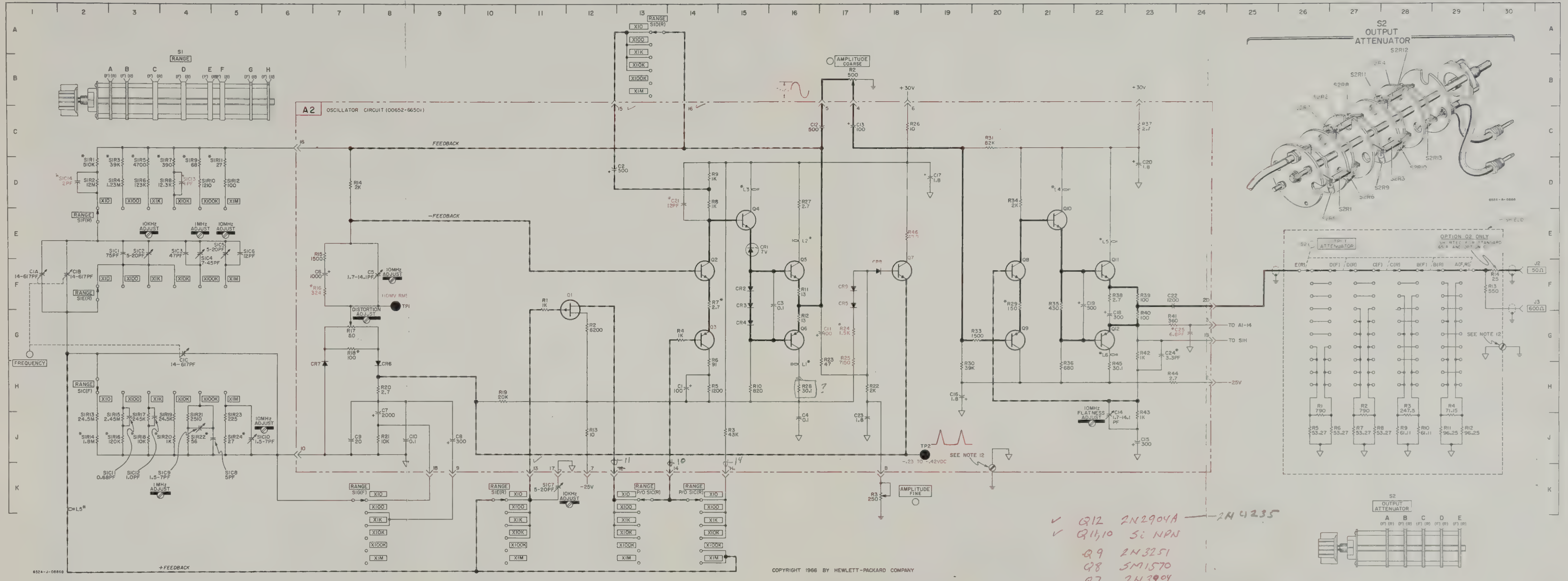



## NOTES

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.
2. COMPONENT VALUES ARE SHOWN AS FOLLOWS UNLESS OTHERWISE NOTED.
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
3. DENOTES ASSEMBLY.
4. DENOTES MAIN SIGNAL PATH.
5. DENOTES FEEDBACK PATH.
6. DENOTES FRONT PANEL MARKING.
7. DENOTES SCREWDRIVER ADJUST.
8. DENOTES FRONT PANEL CONTROL.
9. DENOTES CHASSIS GROUND.
10. DENOTES CIRCUIT GROUND.
11. * AVERAGE VALUE SHOWN, OPTIMUM VALUE SELECTED AT FACTORY.
12. DENOTES GROUND CONNECTION MADE WITH ASSEMBLY MOUNTING SCREWS IN PLACE.
13. DENOTES SHIELDING BEAD.
14. RE[illegible]NCE DESIGNATORS PRINTED IN RED INDICATE BACKDATING [illegible] SEE APPENDIX [illegible]

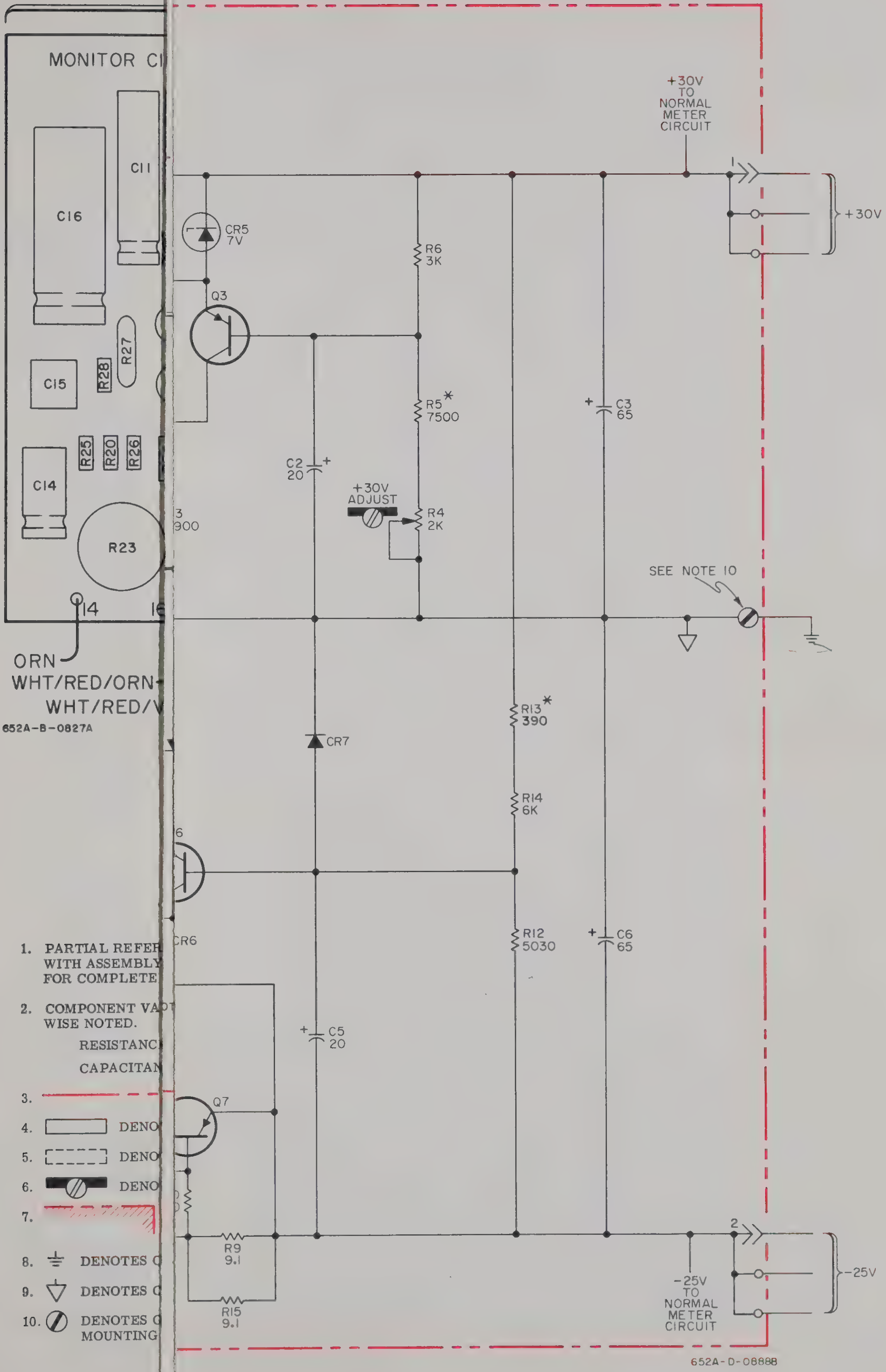
A2 SCHEMATIC
COMPONENT LOCATIONS

| | C | CR | L | Q | R | | R |
|---|---|---|---|---|---|---|---|
| 1 | H14 | E15 | G16 | F12 | F11 | 26 | C18 |
| 2 | D13 | F15 | E16 | F14 | G12 | 27 | D16 |
| 3 | F16 | F15 | D15 | G14 | J15 | 28 | H16 |
| 4 | J16 | G15 | D21 | E15 | G14 | 29 | F20 |
| 5 | F8 | F17 | E22 | F16 | H14 | 30 | H19 |
| 6 | F7 | H8 | G22 | G16 | H14 | 31 | C20 |
| 7 | J8 | H7 | | F18 | F14 | 32 | --- |
| 8 | J9 | F18 | | F20 | D14 | 33 | G20 |
| 9 | J7 | F17 | | G20 | D14 | 34 | D20 |
| 10 | J8 | | | E21 | H15 | 35 | F21 |
| 11 | G17 | | | F22 | F16 | 36 | H21 |
| 12 | C16 | | | G22 | G16 | 37 | C23 |
| 13 | C17 | | | | J12 | 38 | F22 |
| 14 | J22 | | | | D7 | 39 | F23 |
| 15 | J23 | | | | E7 | 40 | G23 |
| 16 | H19 | | | | F7 | 41 | G23 |
| 17 | D19 | | | | G7 | 42 | G23 |
| 18 | G22 | | | | G7 | 43 | J23 |
| 19 | F22 | | | | H10 | 44 | H23 |
| 20 | D23 | | | | H8 | 45 | H22 |
| 21 | D14 | | | | J8 | 46 | E18 |
| 22 | F23 | | | | H17 | | |
| 23 | J17 | | | | G17 | | |
| 24 | G23 | | | | G17 | | |
| 25 | G24 | | | | H17 | | |




✓ Q12 2N2904A — 2N4235
✓ Q11,10 Si NPN
Q9 2N3251
Q8 SM1570
Q7 2N3904
✓ Q6 2N2904A — 2N3134
Q5,4 Si NPN
Q3 2N3906
Q2 2N3904

Figure 6-2. Oscillator Circuit




1. PARTIAL REFER
WITH ASSEMBLY
FOR COMPLETE

2. COMPONENT VA
WISE NOTED.
RESISTANC
CAPACITAN

3.

4. DENO

5. DENO

6. DENO

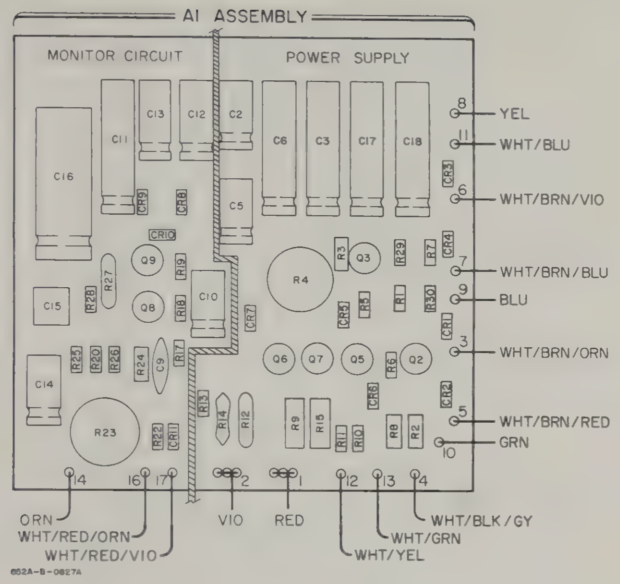
7.

8. DENOTES C

9. DENOTES C

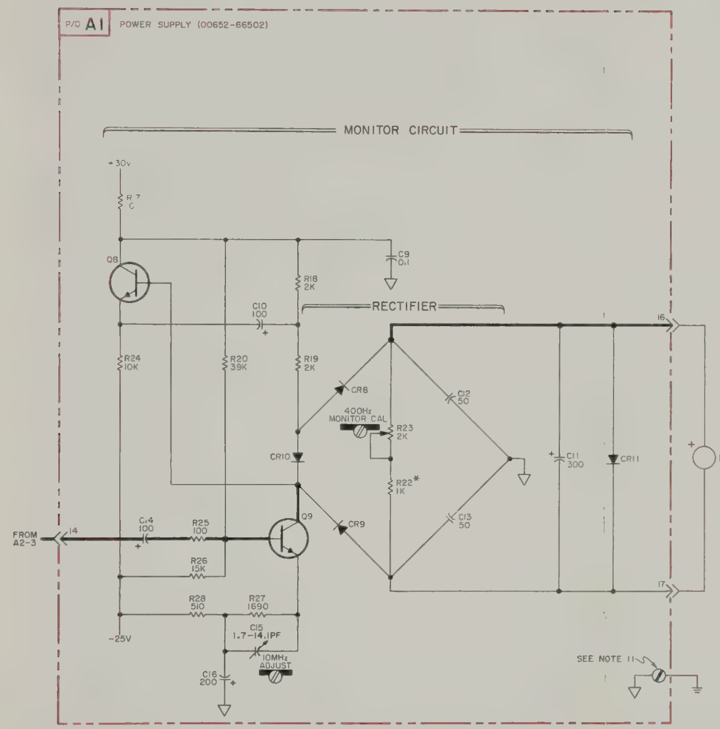
10. DENOTES C
MOUNTING

Figure 6-3. Monitor Circuit and Power Supply




## NOTES

1. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. PREFIX WITH ASSEMBLY OR SUBASSEMBLY DESIGNATION(S) OR BOTH FOR COMPLETE DESIGNATION.
2. COMPONENT VALUES ARE SHOWN AS FOLLOWS UNLESS OTHERWISE NOTED.
   RESISTANCE IN OHMS
   CAPACITANCE IN MICROFARADS
3. DENOTES ASSEMBLY.
4. DENOTES FRONT PANEL MARKING.
5. DENOTES REAR PANEL MARKING.
6. DENOTES SCREWDRIVER ADJUST.
7. DENOTES COMPONENTS NOT MOUNTED ON ASSEMBLY.
8. DENOTES CHASSIS GROUND.
9. DENOTES CIRCUIT GROUND.
10. DENOTES GROUND CONNECTION MADE WITH ASSEMBLY MOUNTING SCREWS IN PLACE.





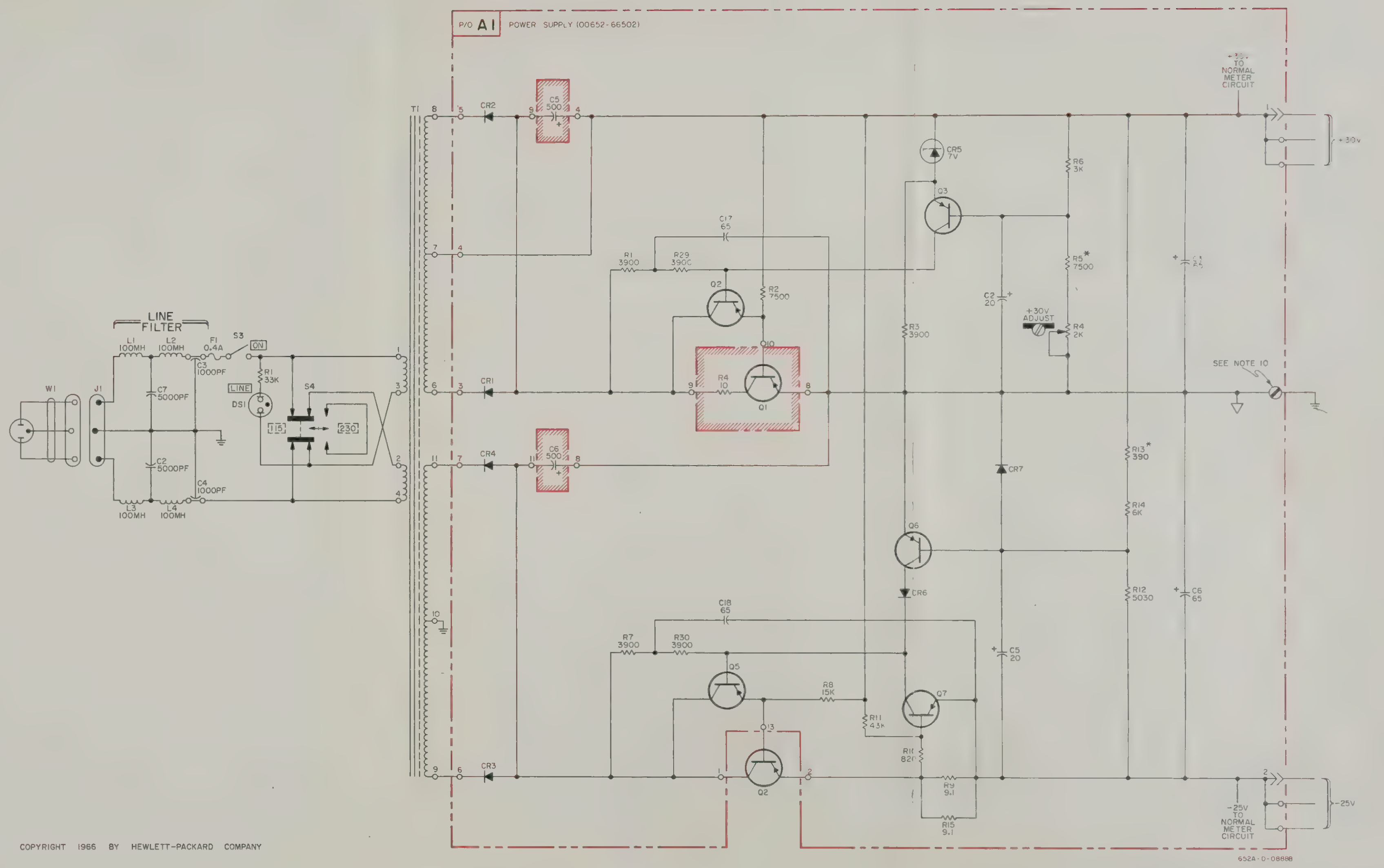






Figure 6-3. Monitor Circuit and Power Supply

# MANUAL CHANGES

MODEL 651B

TEST OSCILLATOR

Manual Serial Prefixed: 811-
-hp- Part No. 00651-90005

► New or revised item

| Instrument Serial Number | Make Manual Changes | Instrument Serial Number | Make Manual Changes |
|---|---|---|---|
| ALL | ERRATA | 961-05251 and above | CHANGE #3 |
| 828-03301 and above | ERRATA | | |
| 911-01911 and above | CHANGE #1 | | |
| 953-05051 and above | CHANGE #2 | | |

ERRATA

Page 1-0, Table 1-1.
Change power requirements to: 115V or 230V, ± 10%, 30W 50 Hz to 400 Hz.

Page 2-1, Paragraph 2-4 and Page 3-1, Paragraph 3-8a:
Change 1000 Hz to 400 Hz.

Page 3-1, Paragraph 3-8g:
Change '$V_m$ = Model 651B Output Monitor Reading' to '$V_m$ = Model 651B Output Monitor voltage indication multiplied by the OUTPUT ATTENUATOR voltage setting.

Page 5-6, Paragraph 5-16.
In the formula shown in step f change $E_3^3$ to $E_3^2$

Table 5-7, middle column:
Change S1C14* to S1C15*.
Change capacitor for X1M RANGE (Increases A2TP2 Voltage) to S1C10, S1C14* and A2C5.

Page 5-10:
Paragraph 5-28e: Change MP2 to MP1
Table 5-8, column headed COUNTER INDICATION:
Add ± between all numbers showing counter indication and tolerance (eg. 100 ± 3 ms, 50 ± 1.5 ms, etc.)

Performance Check Test Card (at end of Section V):
On second page change '5-17. AMPLITUDE STABILITY' to '5-17. HUM AND NOISE.'

Figure 6-2:
Change S1C14* (in parallel with S1R2) to S1C15*.
Add S1C14*, 5.6 pF (in parallel with S1C10).

Page 7-2, Figure 7-1:
Add: MP43 (Spring, thrust) appears behind MP9.

ERRATA (Cont'd)

Table 7-1:

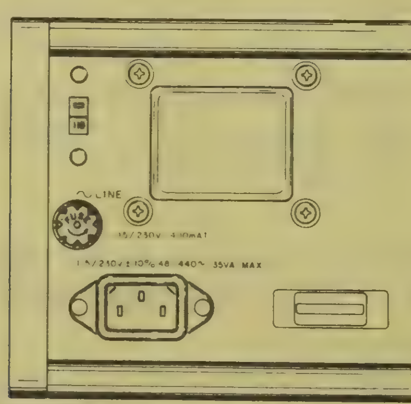
Change -hp- Part No. of A1CR1 thru A1CR4 to 1901-0158.
Change -hp- Part No. of A2Q8 to 1854-0337.
Change -hp- Part No. and description of MP4 to 1460-0114, Wire form.
Change -hp- Part No. of MP24 to 4040-0297.
Add MP43, 5000-0637, Spring: thrust.
Change S1C14* S1C15*.
Add S1C14* capacitor fixed, 5-6 pF, 0150-0044.

CHANGE #1

Page 7-4, Table 7-1:
Change A1Q6 Part No. to 1850-0062.
Page 7-8, Table 7-1:
Change S1C8 to 10 pF (0140-0002).
Page 6-5, Figure 6-2:
Change S1C8 to 10 pF.
Page 7-6, table 7-1:
Change A2R42, A2R43 Part No. to 0757-0159.

CHANGE # 2

Page 6-7/6-8, Figure 6-3:
Change C3 and C4 to 5000 pF.
Delete L1 and L3.
Page 7-6, Table 7-1:
Change C2, C3, C4, and C7 to 5000 pF (0160-3333).
Change J1 Part No. to 1251-2357.
Delete L1 and L3.
Page 7-7, Table 7-1:
Change MP31 Part No. to 00651-00203.
Page7-9, Table 7-1:
Delete all reference designators for cables (W1 through W5).
Add reference designator W1 for power cord.
Change Part No. of power cord to 8120-1348.
Page 3-0, Figure 3-1:
Revise rear panel drawing as follows:



▶ CHANGE #3 Page 7-6:
Change Part No. of F1 to 2110-0340, 250 V.

# SECTION VII
# REPLACEABLE PARTS

## 7-1. INTRODUCTION.

7-2. This section contains information for ordering replacement parts. Table 7-1 lists parts in alphameric order of their reference designators and indicates the description, -hp- part number of each part, together with any applicable notes, and provides the following:

a. Total quantity used in the instrument (TQ column). The total quantity of a part is given the first time the part number appears.

b. Description of the part. (See list of abbreviations below.)

c. Typical manufacturer of the part in a five-digit code. (See Appendix A for list of manufacturers.)

d. Manufacturer's part number.

7-3. Miscellaneous parts are listed at the end of Table 7-1.

## 7-4. ORDERING INFORMATION.

7-5. To obtain replacement parts, address order or inquiry to your local Hewlett-Packard Field Office. (See Appendix B for list of office locations.) Identify parts by their Hewlett-Packard part numbers. Include instrument model and serial numbers.

## 7-6. NON-LISTED PARTS.

7-7. To obtain a part that is not listed, include:

a. Instrument model number.

b. Instrument serial number.

c. Description of the part.

d. Function and location of the part.

DESIGNATORS

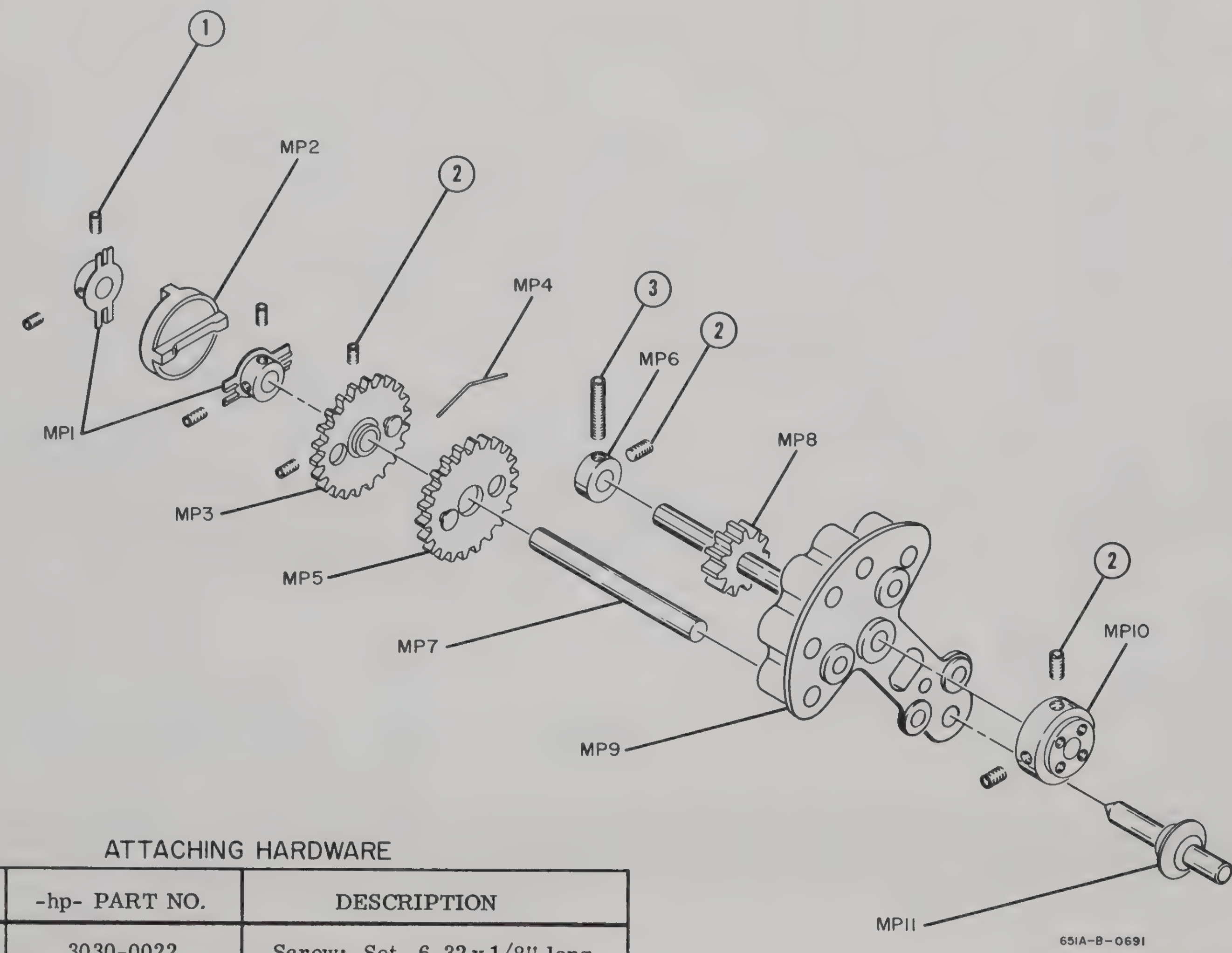
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A | = assembly | F | = fuse | MP | = mechanical part | TC | = thermocouple |
| B | = motor | FL | = filter | P | = plug | V | = vacuum tube, neon bulb, photocell, etc. |
| BT | = battery | HR | = heater | Q | = transistor | W | = cable |
| C | = capacitor | IC | = integrated circuit | QCR | = transistor-diode | X | = socket |
| CR | = diode | J | = jack | R | = resistor | XDS | = lampholder |
| DL | = delay line | K | = relay | RT | = thermistor | XF | = fuseholder |
| DS | = lamp | L | = inductor | S | = switch | Z | = network |
| E | = misc electronic part | M | = meter | T | = transformer | | |

ABBREVIATIONS

| | |
|---|---|
| Ag | = silver |
| Al | = aluminum |
| A | = ampere (s) |
| Au | = gold |
| C | = capacitor |
| cer | = ceramic |
| coef | = coefficient |
| com | = common |
| comp | = composition |
| conn | = connection |
| dep | = deposited |
| DPDT | = double-pole double-throw |
| DPST | = double-pole single-throw |
| elect | = electrolytic |
| encap | = encapsulated |
| F | = farad (s) |
| FET | = field effect transistor |
| fxd | = fixed |
| GaAs | = gallium arsenide |
| GHz | = gigahertz = $10^{+9}$ hertz |
| gd | = guard (ed) |
| Ge | = germanium |
| grd | = ground (ed) |
| H | = henry (ies) |
| Hg | = mercury |
| Hz | = hertz (cycle (s) per second) |
| ID | = inside diameter |
| impg | = impregnated |
| incd | = incandescent |
| ins | = insulation (ed) |
| kΩ | = kilohm (s) = $10^{+3}$ ohms |
| kHz | = kilohertz = $10^{+3}$ hertz |
| L | = inductor |
| lin | = linear taper |
| log | = logarithmic taper |
| m | = milli = $10^{-3}$ |
| mA | = milliampere (s) = $10^{-3}$ amperes |
| MHz | = megahertz = $10^{+6}$ hertz |
| MΩ | = megohm (s) = $10^{+6}$ ohms |
| met flm | = metal film |
| mfr | = manufacturer |
| mtg | = mounting |
| mV | = millivolt (s) = $10^{-3}$ volts |
| μ | = micro = $10^{-6}$ |
| μV | = microvolt (s) = $10^{-6}$ volts |
| my | = Mylar ® |
| nA | = nanoampere (s) = $10^{-9}$ amperes |
| NC | = normally closed |
| Ne | = neon |
| NO | = normally open |
| NPO | = negative positive zero (zero temperature coefficient) |
| ns | = nanosecond (s) = $10^{-9}$ seconds |
| nsr | = not separately replaceable |
| Ω | = ohm (s) |
| obd | = order by description |
| OD | = outside diameter |
| p | = peak |
| pc | = printed circuit |
| pF | = picofarad (s) = $10^{-12}$ farads |
| piv | = peak inverse voltage |
| p/o | = part of |
| pos | = position (s) |
| poly | = polystyrene |
| pot | = potentiometer |
| p-p | = peak-to-peak |
| ppm | = parts per million |
| prec | = precision (temperature coefficient, long term stability, and/or tolerance) |
| R | = resistor |
| Rh | = rhodium |
| rms | = root-mean-square |
| rot | = rotary |
| Se | = selenium |
| sect | = section (s) |
| Si | = silicon |
| sl | = slide |
| SPDT | = single-pole double-throw |
| SPST | = single-pole single-throw |
| Ta | = tantalum |
| TC | = temperature coefficient |
| $TiO_2$ | = titanium dioxide |
| tog | = toggle |
| tol | = tolerance |
| trim | = trimmer |
| TSTR | = transistor |
| V | = volt (s) |
| vacw | = alternating current working voltage |
| var | = variable |
| vdcw | = direct current working voltage |
| W | = watt (s) |
| w/ | = with |
| wiv | = working inverse voltage |
| w/o | = without |
| ww | = wirewound |
| * | = optimum value selected at factory, average value shown (part may be omitted) |
| ** | = no standard type number assigned (selected or special type) |

® Dupont de Nemours

REV 6




ATTACHING HARDWARE

| ITEM | -hp- PART NO. | DESCRIPTION |
|---|---|---|
| 1 | 3030-0022 | Screw: Set, 6-32 x 1/8" long |
| 2 | 3030-0001 | Screw: Set, 8-32 x 3/16" long |
| 3 | 3030-0004 | Screw: Set, 8-32 x 1" long |

Figure 7-1. Frequency Tuning Mechanism

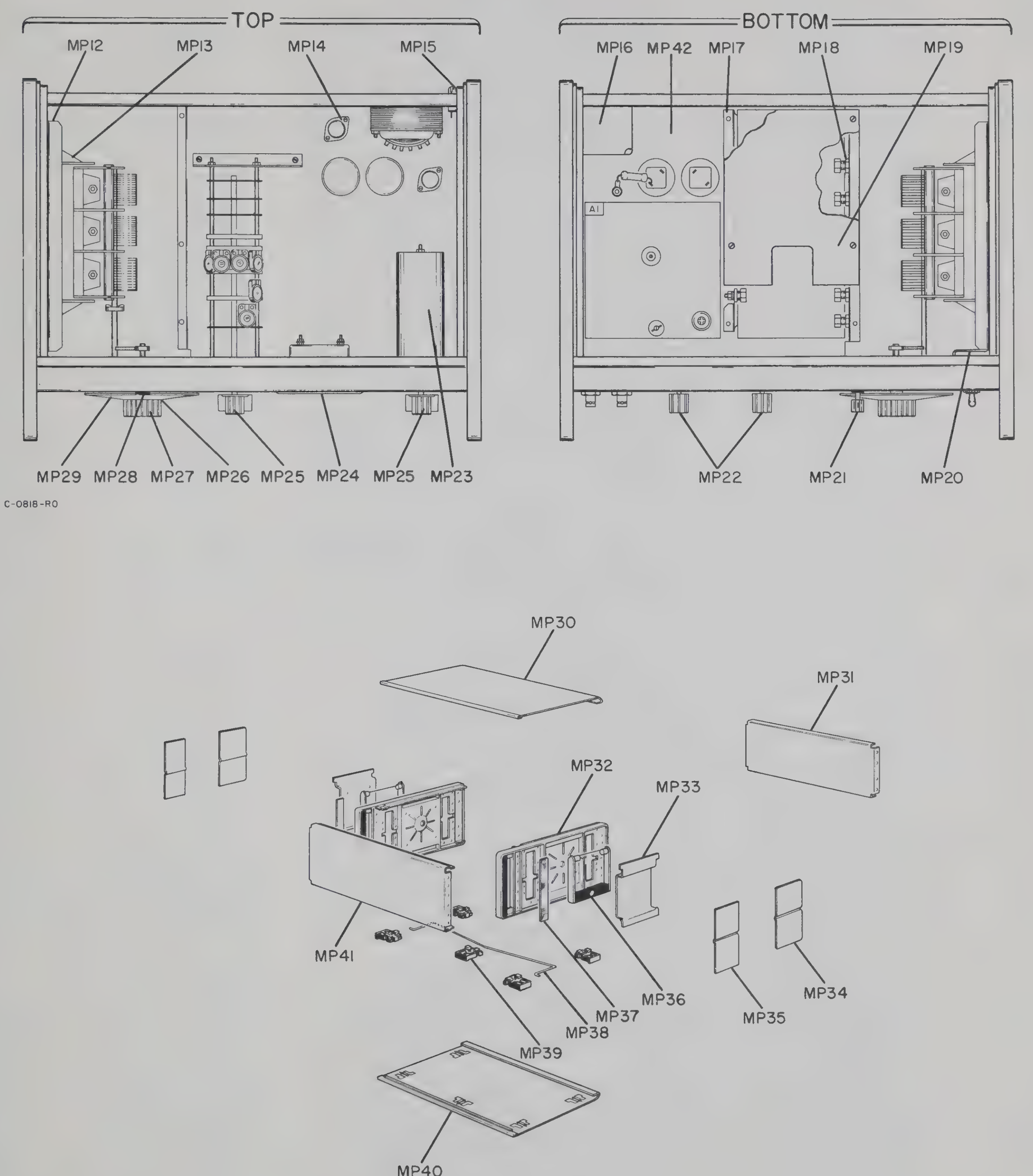



Figure 7-2. Chassis Mechanical Parts

Table 7-1. Replaceable Parts

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A1 | 00652-66502 | | 1 | Pc board: power supply | 28480 | 00652-66502 |
| A1C1 | | | | Not assigned | | |
| A1C2 | 0180-0045 | | 2 | C: fxd Al elect 20 μF +75% -10% 25 vdcw | 56289 | 30D206G025 DB2-DSM |
| A1C3 | 0180-0149 | | 4 | C: fxd Al elect 65 μF +100% -10% 60 vdcw | 56289 | (Type 30D) D36978 |
| A1C4 | | | | Not assigned | | |
| A1C5 | 0180-0045 | | | C: fxd Al elect 20 μF +75% -10% 25 vdcw | 56289 | 30D206G025 DB2-DSM |
| A1C6 | 0180-0149 | | | C: fxd Al elect 65 μF +100% -10% 60 vdcw | 56289 | (Type 30D) D36978 |
| A1C7, A1C8 | | | | Not assigned | | |
| A1C9 | 0150-0084 | | 4 | C: fxd cer 0.1 μF +80% -20% 50 vdcw | 56289 | 33C41 obd |
| A1C10 | 0180-0061 | | 3 | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015DC2-DSM |
| A1C11 | 0180-0062 | | 3 | C: fxd Al elect 300 μF +75% -10% 6 vdcw | 56289 | 30D307G006DF2-DSM |
| A1C12, A1C13 | 0180-0058 | | 2 | C: fxd Al elect 50 μF +75% -10% 25 vdcw | 56289 | 30D506G025CC2-DSM |
| A1C14 | 0180-0061 | | | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015DC2-DSM |
| A1C15 | 0121-0127 | | 3 | C: var air 1.7 to 14.1 pF | 74970 | 189-505-5 |
| A1C16 | 0180-0284 | | 1 | C: fxd Al elect 200 μF +75% -10% 30 vdcw | 56289 | D38559 |
| A1C17, A1C18 | 0180-0149 | | | C: fxd Al elect 65 μF +100% -10% 60 vdcw | 56289 | (Type 30D) D36978 |
| A1CR1 thru A1CR4 | 1901-0026 | | 4 | Diode: Si 200 piv | 04713 | SR 1358-8 obd |
| A1CR5 | 1902-0045 | | 1 | Diode: breakdown 7.32 V ±2% 400 mW glass | 07263 | obd |
| A1CR6, A1CR7 | 1901-0025 | | 9 | Diode: Si 100 mA at +1 V 100 piv 12 pF | 03877 | SG 917 obd |
| A1CR8, A1CR9 | 1901-0347 | | 2 | Diode: Si 8 V 20 mA at +1 V 1.5 pF | 28480 | 1901-0347 |
| A1CR10 | 1910-0016 | | 6 | Diode: Ge 60 wiv | 03877 | S3185G obd |
| A1CR11 | 1901-0025 | | | Diode: Si 100 mA at +1 V 100 piv 12 pF | 03877 | SG 817 obd |
| A1Q1 | | | | Not assigned | | |
| A1Q2 | 1850-0107 | | 2 | TSTR: Ge PNP 2N398A | 04713 | 2N398A |
| A1Q3 | 1853-0007 | | 3 | TSTR: Si PNP 2N3251 | 04713 | 2N3251 |
| A1Q4 | | | | Not assigned | | |
| A1Q5 | 1850-0107 | | | TSTR: Ge PNP 2N398A | 04713 | 2N398A |
| A1Q6, A1Q7 | 1853-0007 | | | TSTR: Si PNP 2N3251 | 04713 | 2N3251 |
| A1Q8 | 1854-0218 | | 2 | TSTR: Si NPN 2N3393 | 24446 | 2N3393 |
| A1Q9 | 1854-0042 | | 2 | TSTR: Si NPN SM1570 | 04713 | SM1570 |
| A1R1 | 0683-3925 | | 4 | R: fxd comp 3900Ω ±5% 1/4 W | 01121 | CB3925 |
| A1R2 | 0686-7525 | | 1 | R: fxd comp 7500Ω ±5% 1/2 W | 01121 | EB7525 |
| A1R3 | 0687-3921 | | 1 | R: fxd comp 3900Ω ±10% 1/2 W | 01121 | EB3921 |
| A1R4 | 2100-0090 | | 1 | R: var comp lin 2000Ω ±30% 0.15 W | 71450 | UPM-70RE (-hp-) obd |
| A1R5* | 0683-7525 | | 1 | R: fxd comp 7500Ω ±5% 1/4 W | 01121 | CB7525 |
| A1R6 | 0683-3025 | | 1 | R: fxd comp 3000Ω ±5% 1/4 W | 01121 | CB3025 |
| A1R7 | 0683-3925 | | | R: fxd comp 3900Ω ±5% 1/4 W | 01121 | CB3925 |
| A1R8 | 0687-1531 | | 1 | R: fxd comp 15 KΩ ±10% 1/2 W | 01121 | EB1531 |
| A1R9 | 0689-0915 | | 2 | R: fxd comp carbon 9.1Ω ±5% 1 W | 01121 | GB91G5 |
| A1R10 | 0683-8215 | | 1 | R: fxd comp 820Ω ±5% 1/4 W | 01121 | CB8215 |
| A1R11 | 0683-4335 | | 2 | R: fxd comp 43 KΩ ±5% 1/4 W | 01121 | CB4335 |
| A1R12 | 0757-0039 | | 1 | R: fxd met flm 5030Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| A1R13* | 0683-3915 | | 2 | R: fxd comp 390Ω ±5% 1/4 W | 01121 | CB3915 |
| A1R14 | 0757-1013 | | 1 | R: fxd met flm 6000Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| A1R15 | 0689-0915 | | | R: fxd comp carbon 9.1Ω ±5% 1 W | 01121 | GB91G5 |
| A1R16 | | | | Not assigned | | |
| A1R17 | 0684-1001 | | 1 | R: fxd comp 10Ω ±10% 1/4 W | 01121 | CB1001 |
| A1R18, A1R19 | 0683-2025 | | 3 | R: fxd comp 2000Ω ±5% 1/4 W | 01121 | CB2025 |
| A1R20 | 0683-3935 | | 2 | R: fxd comp 39 KΩ ±5% 1/4 W | 01121 | CB3935 |
| A1R21 | | | | Not assigned | | |

Table 7-1. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A1R22* | 0683-1025 | | 4 | R: fxd comp 1000Ω ±5% 1/4 W | 01121 | CB1025 |
| A1R23 | 2100-0282 | | 1 | R: var ww 2000Ω ±20% 1-1/2 W | 11236 | 110 obd |
| A1R24 | 0687-1031 | | 1 | R: fxd comp 10 KΩ ±10% 1/2 W | 01121 | EB1031 obd |
| A1R25 | 0684-1011 | | 2 | R: fxd comp 100Ω ±10% 1/4 W | 01121 | CB1011 |
| A1R26 | 0683-1535 | | 1 | R: fxd comp 15 KΩ ±5% 1/4 W | 01121 | CB1535 |
| A1R27 | 0698-0026 | | 1 | R: fxd met flm 1690Ω ±1% 1/2 W | 19701 | MF7C T-O obd |
| A1R28 | 0683-5115 | | 1 | R: fxd comp 510Ω ±5% 1/4 W | 01121 | CB5115 |
| A1R29, A1R30 | 0683-3925 | | | R: fxd comp 3900Ω ±5% 1/4 W | 01121 | CB3925 |
| A2 | 00652-66501 | | 1 | Pc board: oscillator amplifier | 28480 | 00652-66501 |
| A2C1 | 0180-0061 | | | C: fxd Al elect 100 μF +75% -10% 15 vdcw | 56289 | 30D107G015DC2-DSM |
| A2C2 | 0180-0237 | | 1 | C: fxd Al elect 500 μF +75% -10% 25 vdcw | 56289 | 39D507G025HE4-DSB |
| A2C3, A2C4 | 0150-0084 | | | C: fxd cer 0.1 μF +80% -20% 50 vdcw | 56289 | 33C41 obd |
| A2C5 | 0121-0127 | | | C: var air 1.7 to 14.1 pF | 74970 | 189-505-5 |
| A2C6 | 0180-0305 | | 1 | C: fxd Al elect 1000 μF +100% -10% 2.5 vdcw | 56289 | 34D108H2R5FJ4 |
| A2C7 | 0180-0112 | | 1 | C: fxd Al elect 2000 μF 1 vdcw | 56289 | D33239 |
| A2C8 | 0180-0062 | | | C: fxd Al elect 300 μF +75% -10% 6 vdcw | 56289 | 30D307G006DF2-DSM |
| A2C9 | 0180-0076 | | 1 | C: fxd elect 20 μF 25 vdcw | 56289 | 40D206G025DC6-DST |
| A2C10 | 0150-0084 | | | C: fxd cer 0.1 μF +80% -20% 50 vdcw | 56289 | 33C41 obd |
| A2C11 | 0180-0039 | | 2 | C: fxd Al elect 100 μF +75% -10% 3 vdcw | 56289 | 30D107G012CC2-DSM |
| A2C12 | 0180-2151 | | 1 | C: fxd Al elect 500 μF +75% -10% | 56289 | 30D NON POLAR obd |
| A2C13 | 0180-0039 | | | C: fxd Al elect 100 μF +75% -10% 12 vdcw | 56289 | 30D107G012CC2-DSM |
| A2C14 | 0121-0127 | | | C: var air 1.7 to 14.1 pF | 74970 | 189-505-5 |
| A2C15 | 0180-0062 | | | C: fxd Al elect 300 μF +75% -10% 6 vdcw | 56289 | 30D307G006DF2-DSM |
| A2C16, A2C17 | 0180-0101 | | 4 | C: fxd Ta 1.8 μF ±10% 35 vdcw | 56289 | 150D185X9035B2 |
| A2C18 | 0180-0306 | | 1 | C: fxd Al elect 300 μF +100% -10% 15 vdcw | 56289 | 34D307H015FJ4 |
| A2C19 | 0180-0307 | | 1 | C: fxd Al elect 500 μF +100% -10% 15 vdcw | 56289 | 34D507H015FJ4 |
| A2C20 | 0180-0101 | | | C: fxd Ta 1.8 μF ±10% 35 vdcw | 56289 | 150D185X9035B2 |
| A2C21* | 0140-0201 | | 1 | C: fxd mica 12 pF ± 5% | 72136 | obd |
| A2C22 | 0180-1756 | | 1 | C: fxd Al elect 1200 μF +100% -10% | 56289 | Type 34D Special obd |
| A2C23 | 0180-0101 | | | C: fxd Ta 1.8 μF ±10% 35 vdcw | 56289 | 150D185X9035B2 |
| A2C24* | 0150-0022 | | 1 | C: fxd $TiO_2$ 3.3 pF ±10% 500 vdcw | 78488 | Type GA obd |
| A2C25* | 0150-0043 | | 1 | C: fxd $TiO_2$ 6.8 pF 5% 500 vdcw | 78488 | Type GA obd |
| A2CR1 | 1902-0046 | | 1 | Diode: breakdown 7.15 V ±10% 400 mW | 04713 | 10939-139 obd |
| A2CR2 thru A2CR4 | 1901-0025 | | | Diode: Si 100 mA at +1 V 100 piv 12 pF | 03877 | SG-817 |
| A2CR5 thru A2CR7 | 1910-0016 | | | Diode: Ge 60 wiv | 03877 | S3185G obd |
| A2CR8 | 1901-0040 | | 1 | Diode: Si | 03877 | SG-5050 |
| A2CR9 | 1910-0016 | | | Diode: Ge 60 wiv | 03877 | S3185G obd |
| A2L1* thru A2L6* | 9170-0016 | | | Bead: shielding | 02114 | 56-590-65/3B |
| A2Q1 | 1855-0082 | | 1 | TSTR: P FET channel** | 28480 | 1855-0082 |
| A2Q2 | 1854-0215 | | | TSTR: Si NPN 2N3904 | 04713 | SDS 3611 obd |
| A2Q3 | 1853-0036 | | 1 | TSTR: Si PNP 2N3906 | 04713 | 2N3906 |
| A2Q4, A2Q5 | 1854-0254 | | 4 | TSTR: Si NPN** | 28480 | 1854-0254 |
| A2Q6 | 1853-0012 | | 2 | TSTR: Si PNP 2N2904A | 04713 | 2N2904A |
| A2Q7 | 1854-0215 | | | TSTR: Si NPN 2N3904 | 24446 | 2N3904 |
| A2Q8 | 1854-0042 | | | TSTR: Si NPN SM1570 | 04713 | SM1570 |
| A2Q9 | 1853-0007 | | 1 | TSTR: Si PNP 2N3251 | 04713 | 2N3251 |
| A2Q10, A2Q11 | 1854-0254 | | | TSTR: Si NPN ** | 28480 | 1854-0254 |

Table 7-1. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| A2Q12 | 1853-0012 | | | TSTR: Si PNP 2N2904A | 04713 | 2N2904A |
| A2R1 | 0687-1021 | | 1 | R: fxd comp 1000Ω ±10% 1/2 W | 01121 | EB1021 |
| A2R2 | 0683-6225 | | 1 | R: fxd comp 6200Ω ±5% 1/4 W | 01121 | CB6225 |
| A2R3 | 0683-4335 | | | R: fxd comp 43 KΩ ±5% 1/4 W | 01121 | CB4335 |
| A2R4 | 0683-1025 | | | R: fxd comp 1000Ω ±5% 1/4 W | 01121 | CB1025 |
| A2R5 | 0684-1221 | | 1 | R: fxd comp 1200Ω ±10% 1/4 W | 01121 | CB1221 |
| A2R6 | 0683-9105 | | 1 | R: fxd comp 91Ω ±5% 1/4 W | 01121 | CB9105 |
| A2R7* | 0683-0275 | | 6 | R: fxd comp 2.7Ω ± 5% 1/4 W | 01121 | CB27G5 |
| A2R8, A2R9 | 0686-1025 | | 2 | R: fxd comp 1000Ω ±5% 1/2 W | 01121 | EB1025 |
| A2R10 | 0693-8211 | | 1 | R: fxd comp carbon 820Ω ±10% 2 W | 01121 | HB8211 |
| A2R11, A2R12 | 0686-1305 | | 2 | R: fxd comp 13Ω ±5% 1/2 W | 01121 | EB1305 |
| A2R13 | 0687-1001 | | 2 | R: fxd comp 10Ω ±10% 1/2 W | 01121 | EB1001 |
| A2R14 | 0757-0739 | | 2 | R: fxd met flm 2000Ω ±1% 1/4 W | 19701 | MF6C T-O obd |
| A2R15 | 0757-0736 | | 1 | R: fxd met flm 1500Ω ±1% 1/4 W | 19701 | MF6C T-O obd |
| A2R16* | 0698-4450 | | 1 | R: fxd met flm 324Ω ±1% 1/8 W | 91637 | MFF-1/8 T-1 obd |
| A2R17 | 2100-2604 | | 1 | R: var comp lin 50Ω ±10% 0.15 W | 01121 | Type SV 5001 obd |
| A2R18* | 0684-1011 | | | R: fxd comp 100Ω ±10% 1/4 W | 01121 | CB1011 |
| A2R19 | 0683-2035 | | 1 | R: fxd comp 20 KΩ ±5% 1/4 W | 01121 | CB2035 |
| A2R20 | 0683-0275 | | | R: fxd comp 2.7Ω ±5% 1/4 W | 01121 | CB27G5 |
| A2R21 | 0684-1031 | | 4 | R: fxd comp 10 KΩ ±10% 1/4 W | 01121 | CB1031 |
| A2R22 | 0757-0739 | | | R: fxd met flm 2000Ω ±1% 1/4 W | 19701 | MF6C T-O obd |
| A2R23 | 0683-4705 | | 1 | R: fxd comp 47Ω ±5% 1/4 W | 01121 | CB4705 |
| A2R24* | 0683-1525 | | 1 | R: fxd comp 1500Ω ±5% 1/4 W | 01121 | CB1525 |
| A2R25 | 0698-4657 | | 1 | R: fxd met flm 7150Ω ±1% 1/4 W | 91637 | MFF-1/4 T-1 obd |
| A2R26 | 0687-1001 | | | R: fxd comp 10Ω ±10% 1/2 W | 01121 | EB1001 |
| A2R27 | 0683-0275 | | | R: fxd comp 2.7Ω ±5% 1/4 W | 01121 | CB27G5 |
| A2R28 | 0757-0500 | | | R: fxd comp 30.1Ω ±1% 1/4 W | 19701 | MF6C T-O obd |
| A2R29* | 0684-1511 | | 1 | R: fxd comp 150Ω ±10% 1/4 W | 01121 | CB1511 |
| A2R30 | 0683-3935 | | | R: fxd comp 39 KΩ ±5% 1/4 W | 01121 | CB3935 |
| A2R31 | 0683-8235 | | 1 | R: fxd comp 82 KΩ ±5% 1/4 W | 01121 | CB8235 |
| A2R32 | | | | Not assigned | | |
| A2R33 | 0684-1521 | | 2 | R: fxd comp 1500Ω ±10% 1/4 W | 01121 | CB1521 |
| A2R34 | 0686-2025 | | 1 | R: fxd comp 2000Ω ±5% 1/2 W | 01121 | EB2025 |
| A2R35 | 0689-4315 | | 1 | R: fxd comp carbon 430Ω ±5% 1 W | 01121 | GB4315 |
| A2R36 | 0693-6811 | | 1 | R: fxd comp carbon 680Ω ±10% 2 W | 01121 | HB6811 |
| A2R37, A2R38 | 0683-0275 | | | R: fxd comp 2.7Ω ±5% 1/4 W | 01121 | CB27G5 |
| A2R39, A2R40 | 0757-1012 | | 2 | R: fxd met flm 100Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| A2R41 | 0683-3615 | | 1 | R: fxd comp 360Ω ±5% 1/4 W | 01121 | CB3615 |
| A2R42, A2R43 | 0757-0154 | | | R: fxd met flm 1000Ω ±1% 1/2 W | 91637 | MFF T-O obd |
| A2R44 | 0683-0275 | | | R: fxd comp 2.7Ω ±5% 1/4 W | 01121 | CB27G5 |
| A2R45 | 0757-0500 | | 1 | R: fxd met flm 30.1Ω ±1% 1/4 W | 75042 | CEB T-O obd |
| A2R46 | 0757-0277 | | 1 | R: fxd met flm 49.9 Ω ±1% 1/8 W | 91637 | MFF-1/8 T-1 obd |
| C1A thru C1C | 0121-0018 | | 1 | C: var air 3-sect 14.75 pF to 617.75 pF | 28480 | 0121-0018 |
| C2 | 0150-0014 | | 2 | C: fxd cer 0.005 μF 500 vdcw | 04222 | D1-4 obd |
| C3, C4 | 0150-0005 | | 2 | C: fxd cer 1000 pF ±20% 500 vdcw | 04222 | Type CFS-1 obd |
| C5, C6 | 0180-0047 | | 2 | C: fxd Al elect 500 μF 75 vdcw | 56289 | D32443 obd |
| C7 | 0150-0014 | | | C: fxd cer 0.005 μF 500 vdcw | 04222 | D1-4 obd |
| DS1 | 2140-0015 | | 1 | Lamp: neon T-2 bulb NE2H | 24446 | obd |
| | 5040-0234 | | 1 | Pilot light: jewel | 28480 | 5040-0234 |
| | 5040-0235 | | 1 | Pilot light: base | 28480 | 5040-0235 |
| F1 | 2110-0019 | | 1 | Fuse: 0.4 A slow-blow 125 V | 75915 | 313.400 obd |
| J1 | 1251-0148 | | 1 | Connector: ac power cord receptacle | 87930 | 1065-1 obd |
| L1 thru L4 | 9140-0029 | | 4 | Coil: radio frequency 100 μH | 99848 | 3100-15-101 |
| L5* | 9170-0016 | | | Bead: shielding | 02114 | 56-590-65/3B |

Table 7-1. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| M1 (Std. inst. only) | 1120-0924 | | 1 | Meter | 55026 | 1332 obd |
| M1 (Opt. 01 only) | 1120-0925 | | 1 | Meter | 55026 | 1332 obd |
| M1 (Opt. 02 only) | 1120-0926 | | 1 | Meter | 55026 | 1332 obd |
| MP1 | 1500-0002 | | 2 | Yoke: flexible coupler | 76487 | Single yoke portion of 39006 coupler |
| MP2 | 5040-0212 | | 1 | Insulator: flexible coupling | 28480 | 5040-0212 |
| MP3 | 5060-0021 | | 1 | Gear assembly | 28480 | 5060-0021 |
| MP4 | 5000-0637 | | 1 | Spring: thrust | 28480 | 5000-0637 |
| MP5 | 5060-0020 | | 1 | Gear assembly | 28480 | 5060-0020 |
| MP6 | 5020-0233 | | 1 | Collar | 28480 | 5020-0233 |
| MP7 | 5020-0348 | | 1 | Shaft | 28480 | 5020-0348 |
| MP8 | 5020-0641 | | 1 | Shaft: spur gear | 28480 | 5020-0641 |
| MP9 | 5020-0639 | | 1 | Casting: Capacitor drive assembly | 28480 | 5020-0639 |
| MP10 | 5020-0630 | | 1 | Hub: dial | 28480 | 5020-0630 |
| MP11 | 5040-0607 | | 1 | Disc assembly: vernier drive | 28480 | 5040-0607 |
| MP12 | 00651-00102 | | 1 | Plate: capacitor | 28480 | 00651-00102 |
| MP13 | 5040-0631 | | 2 | Bracket: capacitor mount | 28480 | 5040-0631 |
| MP14 | 1200-0043 | | 2 | Insulator: TSTR mounting | 000LB | 293011 obd |
| MP15 | 1400-0084 | | 1 | Holder: fuse extractor post type for single 3 AG cartridge fuse | 75915 | 342014 obd |
| MP16 | 00651-05503 | | 1 | Shield: filter | 28480 | 00651-05503 |
| MP17 | 00652-05506 | | 1 | Shield: separates board | 28480 | 00652-05506 |
| MP18 | 1205-0008 | | 6 | Body: heat sink | 13103 | 1101-24-2 |
| MP19 | 00652-04101 | | 1 | Plate: cover over A2 board | 28480 | 00652-04101 |
| MP20 | 00651-05501 | | 1 | Shield: power over switch | 28480 | 00651-05501 |
| MP21 | 0370-0025 | | 1 | Knob: round black vernier | 28480 | 0370-0025 |
| MP22 | 0370-0026 | | 2 | Knob: round black | 28480 | 0370-0026 |
| MP23 | 00651-05504 | | 1 | Shield: outer cover | 28480 | 00651-05504 |
| MP24 | 5040-0685 | | 1 | Bezel: meter window | 28480 | 5040-0685 |
| MP25 | 0370-0112 | | 2 | Knob: bar skirted black | 28480 | 0370-0112 |
| MP26 | 61B-40D-4 | | 1 | Plate: frequency dial | 28480 | 61B-40D-4 |
| MP27 | 0370-0160 | | 1 | Knob: round black dial | 28480 | 0370-0160 |
| MP28 | 5040-0642 | | 1 | Indicator: dial | 28480 | 5040-0642 |
| MP29 | 00651-04001 | | 1 | Dial | 28480 | 00651-04401 |
| MP30 | 5060-0739 | | 1 | Cover assembly: top 11" long | 28480 | 5060-0739 |
| Attaching Hardware: | 2370-0013 | | 2 | Screw: machine | 73076 | obd |
| | 0510-0075 | | 2 | Nut: sheet metal | 78553 | C11351-632-24B |
| MP31 | 00651-00202 | | 1 | Panel: rear | 28480 | 00651-00202 |
| MP32 | 5060-0731 | | 2 | Frame assembly: 5 x 11 full module | 28480 | 5060-0731 |
| MP33 | 5060-0766 | | 2 | Retainer: handle 5" high | 28480 | 5060-0766 |
| Attaching Hardware: | 2515-0017 | | 2 | Screw: machine | 77250 | obd |
| MP34 | 5000-0732 | | 2 | Cover: side rear 5 x 11 full module | 28480 | 5000-0732 |
| Attaching Hardware: | 2370-0016 | | 2 | Screw: machine | 80120 | obd |
| MP35 | 5000-0733 | | 2 | Cover: side front 5 x 11 full module | 28480 | 5000-0733 |
| Attaching Hardware: | 2370-0016 | | 2 | Screw: machine | 80120 | obd |
| MP36 | 5060-0222 | | 2 | Handle assembly: 5" high side | 28480 | 5060-0222 |
| MP37 | 5000-0051 | | 2 | Cabinet trim | 28480 | 5000-0051 |
| MP38 | 1490-0030 | | 1 | Stand: tilt stainless steel rod | 91260 | obd |
| MP39 | 5060-0767 | | 5 | Foot assembly: full module | 28480 | 5060-0767 |
| MP40 | 5060-0751 | | 1 | Cover assembly: bottom 11" long | 28480 | 5060-0751 |
| Attaching Hardware: | 2370-0013 | | 2 | Screw: machine | 73076 | obd |
| | 0510-0075 | | 2 | Nut: sheet metal | 78553 | C11351-632-24B |

Table 7-1. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| MP41 (Std. inst. only) | 00651-00205 | | 1 | Panel: front | 28480 | 00651-00205 |
| MP41 (Opt. 01 only) | 00651-00206 | | 1 | Panel: front | 28480 | 00651-00206 |
| MP41 (Opt. 02 only) | 00651-00207 | | 1 | Panel: front | 28480 | 00651-00207 |
| MP42 | 00651-00103 | | 1 | Deck: main | 28480 | 00651-00103 |
| Q1, Q2 | 1850-0098 | | 2 | TSTR: Ge PNP* | 28480 | 1850-0098 |
| R1 | 0684-3331 | | 1 | R: fxd comp 33 KΩ ±10% 1/4 W | 01121 | CB3331 |
| R2 | 2100-0732 | | 1 | R: var lin comp 500Ω 2-1/4 W | 01121 | Type J obd |
| R3 | 2100-0079 | | 1 | R: var lin comp 240Ω ±10% 2-1/4 W | 01121 | Type J obd |
| R4 | 0766-0029 | | 1 | R: fxd met oxide 10Ω ±2% 3 W | 07115 | LPI-3 obd |
| S1 | 00651-61901 | | 1 | Switch assembly: range | 28480 | 00651-61901 |
| S1C1 | 0140-0040 | | 1 | C: fxd mica 75 pF ±5% | 04062 | RCM 15E 750J |
| S1C2 | 0130-0006 | | 3 | C: var cer 5 to 20 pF | 72982 | 503 000 B2PO28R |
| S1C3 | 0140-0032 | | 1 | C: fxd mica 47 pF ±10% | 04062 | RCM 15F 470K |
| S1C4 | 0130-0001 | | 1 | C: var cer 7 to 45 pF | 72982 | 503-000-D2PO-33R |
| S1C5 | 0130-0006 | | | C: var cer 5 to 20 pF | 72982 | 503 000 B2PO28R |
| S1C6 | 0160-0987 | | 1 | C: fxd mica 12 pF ±5% | 04062 | RDM15C120J5S |
| S1C7 | 0130-0006 | | | C: var cer 5 to 20 pF | 72982 | 503 000 B2PO28R |
| S1C8 | 0140-0001 | | 1 | C: fxd mica 5 pF ±20% | 04062 | RCM15C050M |
| S1C9, S1C10 | 0130-0003 | | 2 | C: var cer 1.5 to 7 pF | 72982 | 503-000 COPO-10R |
| S1C11 | 0150-0046 | | 1 | C: fxd 0.68 pF ±5% 500 vdcw | 78488 | Type GA obd |
| S1C12, S1C13* | 0150-0029 | | 2 | C: fxd 1 pF ±10% 500 vdcw | 78488 | Type GA obd |
| S1C14* | 0150-0031 | | 1 | C: fxd 2 pF ±5% 500 vdcw | 78488 | Type GA obd |
| S1R1* | 0686-5145 | | 1 | R: fxd comp 510 KΩ ±5% 1/2 W | 01121 | EB5145 |
| S1R2 | 0730-0145 | | 1 | R: fxd carbon flm 12 MΩ ±1% 1 W | 91637 | DC-1 obd |
| S1R3* | 0687-3931 | | 1 | R: fxd comp 39 KΩ ± 10% 1/2 W | 01121 | EB3931 |
| S1R4 | 0757-0983 | | 1 | R: fxd met flm 1.23 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R5* | 0687-4721 | | 1 | R: fxd comp 4700Ω ±10% 1/2 W | 01121 | EB4721 |
| S1R6 | 0757-0981 | | 1 | R: fxd met flm 123 KΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R7* | 0687-3911 | | 1 | R: fxd comp 390Ω ±10% 1/2 W | 01121 | EB3911 |
| S1R8 | 0757-0042 | | 1 | R: fxd met flm 12.3 KΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R9* | 0687-6801 | | 1 | R: fxd comp 68Ω ±10% 1/2 W | 01121 | EB6801 |
| S1R10 | 0757-0821 | | 1 | R: fxd met flm 1210Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R11* | 0687-2701 | | 2 | R: fxd comp 27Ω ±10% 1/2 W | 01121 | EB2701 |
| S1R12 | 0757-0198 | | 1 | R: fxd met flm 100Ω ±1% 1/2 W | 19701 | MF7C T-O obd |
| S1R13 | 0733-0006 | | 1 | R: fxd carbon flm 24.5 MΩ ±1% 2 W | 91637 | DC-2 obd |
| S1R14 | 0686-1855 | | 1 | R: fxd comp 1.8 MΩ ±5% 1/2 W | 01121 | EB1855 |
| S1R15 | 0757-1017 | | 1 | R: fxd met flm 2.45 MΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R16* | 0686-1245 | | 1 | R: fxd comp 120 KΩ ±5% 1/2 W | 01121 | EB1245 |
| S1R17 | 0757-0982 | | 1 | R: fxd met flm 245 KΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R18* | 0687-1031 | | 1 | R: fxd comp 10 KΩ ±10% 1/2 W | 01121 | EB1031 |
| S1R19 | 0757-1014 | | 1 | R: fxd met flm 24.5 KΩ ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R20* | 0687-1021 | | 1 | R: fxd comp 1000Ω ±10% 1/2 W | 01121 | EB1021 |
| S1R21 | 0757-0038 | | 1 | R: fxd met flm 2510Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R22* | 0687-5601 | | 1 | R: fxd comp 56 Ω ±10% 1/2 W | 01121 | EB5601 |
| S1R23 | 0757-0980 | | 1 | R: fxd met flm 225Ω ±1% 1/2 W | 75042 | CEC T-O obd |
| S1R24* | 0687-2701 | | 1 | R: fxd comp 27Ω ±10% 1/2 W | 01121 | EB2701 |
| S2 (Std. inst. and Opt. 01 only) | 00651-63402 | | 1 | Attenuator Assembly for standard instrument and Opt. 01 only, includes R1 through R13. | 28480 | 00651-63402 |
| S2 (Opt. 02 only) | 00651-63403 | | | Attenuator Assembly for Opt. 02 only, includes R1 through R14. | 28480 | 00651-63403 |
| S2R1, S2R2 | 0757-1009 | | 2 | R: fxd met flm 790Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R3 | 0757-1008 | | 1 | R: fxd met flm 247.5Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |

Table 7-1. Replaceable Parts (Cont'd)

| REFERENCE DESIGNATOR | -hp- PART NO. | | TQ | DESCRIPTION | MFR. | MFR. PART NO. |
|---|---|---|---|---|---|---|
| S2R4 | 0757-1006 | | 1 | R: fxd met flm 71.15Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R5 thru S2R8 | 0757-1004 | | 1 | R: fxd met flm 53.27Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R9, S2R10 | 0757-1005 | | 2 | R: fxd met flm 61.11Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R11, S2R12 | 0757-1007 | | 2 | R: fxd met flm 96.25Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R13 | 0757-1016 | | 1 | R: fxd met flm 550Ω ±0.25% 1/2 W | 75042 | CEC T-O obd |
| S2R14 (Opt.02 only) | 0757-1025 | | 1 | R: fxd prec met flm 25.0Ω ±1% 1/4 W | 19701 | MF6CT-O obd |
| S3 | 3101-0036 | | 1 | Switch: toggle power SPST | 88140 | 8928K61 |
| S4 | 3101-0033 | | 1 | Switch: slide DPDT 115/230 V | 79727 | G:-326 obd |
| T1 | 9100-0294 | | 1 | Transformer | 28480 | 9100-0294 |
| W1 | 00651-61603 | | 1 | Cable: main | 28480 | 00651-61603 |
| W2 | 00651-61604 | | 1 | Cable: power | 28480 | 00651-61604 |
| W3 | 00651-61602 | | 1 | Cable assembly: attenuator input | 28480 | 00651-61602 |
| W4, W5 | 00651-61601 | | 2 | Cable assembly: attenuator output | 28480 | 00651-61601 |
| | | | | MISCELLANEOUS | | |
| | 8120-0078 | | 1 | Cord: power 7.5 feet | 70903 | KH-4147 obd |
| | 00651-90005 | | 1 | Manual: operating and service | 28480 | 00651-90004 |
| | 5060-0775 | | 1 | Rack mount kit | 28480 | 5060-0775 |

## CODE LIST OF MANUFACTURERS

The following code numbers are from the Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) and their latest supplements. The date of revision and the date of the supplements used appear at the bottom of each page. Alphabetical codes have been arbitrarily assigned to suppliers not appearing in the H4 Handbooks.

| Code No. | Manufacturer | Address |
|---|---|---|
| 00000 | U.S.A. Common | Any supplier of U.S. |
| 00136 | McCoy Electronics | Mount Holly Springs, Pa. |
| 00213 | Sage Electronics Corp. | Rochester, N.Y. |
| 00287 | Cemco Inc. | Danielson, Conn. |
| 00334 | Humidial | Colton, Calif. |
| 00348 | Microtron Co., Inc. | Valley Stream, N.Y. |
| 00373 | Garlock Inc. | Cherry Hill, N.J. |
| 00656 | Aerovox Corp. | New Bedford, Mass. |
| 00779 | Amp. Inc. | Harrisburg, Pa. |
| 00781 | Aircraft Radio Corp. | Boonton, N.J. |
| 00815 | Northern Engineering Laboratories, Inc. | Burlington, Wis. |
| 00853 | Sangamo Electric Co., Pickens Div. | Pickens, S.C. |
| 00866 | Goe Engineering Co. | City of Industry, Cal. |
| 00891 | Carl E. Holmes Corp. | Los Angeles, Calif. |
| 00929 | Microlab Inc. | Livingston, N.J. |
| 01002 | General Electric Co., Capacitor Dept. | Hudson Falls, N.Y. |
| 01009 | Alden Products Co. | Brockton, Mass. |
| 01121 | Allen Bradley Co. | Milwaukee, Wis. |
| 01255 | Litton Industries, Inc. | Beverly Hills, Calif. |
| 01281 | TRW Semiconductors, Inc. | Lawndale, Calif. |
| 01295 | Texas Instruments, Inc., Transistor Products Div. | Dallas, Texas |
| 01349 | The Alliance Mfg. Co. | Alliance, Ohio |
| 01589 | Pacific Relays, Inc. | Van Nuys, Calif. |
| 01930 | Amerock Corp. | Rockford, Ill. |
| 01961 | Pulse Engineering Co. | Santa Clara, Calif. |
| 02114 | Ferroxcube Corp. of America | Saugerties, N.Y. |
| 02116 | Wheelock Signals, Inc. | Long Branch, N.J. |
| 02286 | Cole Rubber and Plastics Inc. | Sunnyvale, Calif. |
| 02660 | Amphenol-Borg Electronics Corp. | Chicago, Ill. |
| 02735 | Radio Corp. of America, Semiconductor and Materials Div. | Somerville, N.J. |
| 02771 | Vocaline Co. of America, Inc. | Old Saybrook, Conn. |
| 02777 | Hopkins Engineering Co. | San Fernando, Calif. |
| 03508 | G.E. Semiconductor Prod. Dept. | Syracuse, N.Y. |
| 03705 | Apex Machine & Tool Co. | Dayton, Ohio |
| 03797 | Eldema Corp. | Compton, Calif. |
| 03818 | Parker Seal Co. | Los Angeles, Calif. |
| 03877 | Transitron Electric Corp. | Wakefield, Mass. |
| 03888 | Pyrofilm Resistor Co., Inc. | Cedar Knolls, N.J. |
| 03954 | Singer Co., Diehl Div. Finderne Plant | Sumerville, N.J. |
| 04009 | Arrow, Hart and Hegeman Elect. Co. | Hartford, Conn. |
| 04013 | Taurus Corp. | Lambertville, N.J. |
| 04062 | Arco Electronic Inc. | Great Neck, N.Y. |
| 04222 | Hi-Q Division of Aerovox | Myrtle Beach, S.C. |
| 04354 | Precision Paper Tube Co. | Wheeling, Ill. |
| 04404 | Dymec Division of Hewlett-Packard Co. | Palo Alto, Calif. |
| 04651 | Sylvania Electric Products, Microwave Device Div. | Mountain View, Calif. |
| 04713 | Motorola, Inc., Semiconductor Prod. Div. | Phoenix, Arizona |
| 04732 | Filtron Co., Inc. Western Div. | Culver City, Calif. |
| 04773 | Automatic Electric Co. | Northlake, Ill. |
| 04796 | Sequoia Wire Co. | Redwood City, Calif. |
| 04811 | Precision Coil Spring Co. | El Monte, Calif. |
| 04870 | P.M. Motor Company | Westchester, Ill. |
| 04919 | Component Mfg. Service Co. | W. Bridgewater, Mass. |
| 05006 | Twentieth Century Plastics, Inc. | Los Angeles, Calif. |
| 05277 | Westinghouse Electric Corp. Semi-Conductor Dept. | Youngwood, Pa. |
| 05347 | Ultronix, Inc. | San Mateo, Calif. |
| 05397 | Union Carbide Corp., Linde Div., Kemet Dept. | Cleveland, Ohio |
| 05574 | Viking Ind. Inc. | Canoga Park, Calif. |
| 05593 | Illumitronic Engineering Co. | Sunnyvale, Calif. |
| 05616 | Cosmo Plastic (c/o Electrical Spec. Co.) | Cleveland, Ohio |
| 05624 | Barber Colman Co. | Rockford, Ill. |
| 05728 | Tiffen Optical Co. | Roslyn Heights, Long Island, N.Y. |
| 05729 | Metro-Tel Corp. | Westbury, N.Y. |
| 05783 | Stewart Engineering Co. | Santa Cruz, Calif. |
| 05820 | Wakefield Engineering Inc. | Wakefield, Mass. |
| 06004 | Bassick Co., Div. of Stewart Warner Corp. | Bridgeport, Conn. |
| 06090 | Raychem Corp. | Redwood City, Calif. |
| 06175 | Bausch and Lomb Optical Co. | Rochester, N.Y. |
| 06402 | E.T.A. Products Co. of America | Chicago, Ill. |
| 06540 | Amatom Electronic Hardware Co., Inc. | New Rochelle, N.Y. |
| 06555 | Beede Electrical Instrument Co., Inc. | Penacook, N.H. |
| 06666 | General Devices Co., Inc. | Indianapolis, Ind. |
| 06751 | Semcor Div. Components Inc. | Phoenix, Ariz. |
| 06812 | Torrington Mfg. Co., West Div. | Van Nuys, Calif. |
| 06980 | Varian Assoc. Eimac Div. | San Carlos, Calif. |
| 07088 | Kelvin Electric Co. | Van Nuys, Calif. |
| 07126 | Digitran Co. | Pasadena, Calif. |
| 07137 | Transistor Electronics Corp. | Minneapolis, Minn. |
| 07138 | Westinghouse Electric Corp. Electronic Tube Div. | Elmira, N.Y. |
| 07149 | Filmohm Corp. | New York, N.Y. |
| 07233 | Cinch-Graphik Co. | City of Industry, Calif. |
| 07256 | Silicon Transistor Corp. | Carle Place, N.Y. |
| 07261 | Avnet Corp. | Culver City, Calif. |
| 07263 | Fairchild Camera & Inst. Corp. Semiconductor Div. | Mountain View, Calif. |
| 07322 | Minnesota Rubber Co. | Minneapolis, Minn. |
| 07387 | Birtcher Corp., The | Monterey Park, Calif. |
| 07397 | Sylvania Elect. Prod. Inc., Mt. View Operations | Mountain View, Calif. |
| 07700 | Technical Wire Products Inc. | Cranford, N.J. |
| 07829 | Bodine Elect. Co. | Chicago, Ill. |
| 07910 | Continental Device Corp. | Hawthorne, Calif. |
| 07933 | Raytheon Mfg. Co., Semiconductor Div. | Mountain View, Calif. |
| 07980 | Hewlett-Packard Co., Boonton Radio Div. | Rockaway, N.J. |
| 08145 | U.S. Engineering Co. | Los Angeles, Calif. |
| 08289 | Blinn, Delbert Co. | Pomona, Calif. |
| 08358 | Burgess Battery Co. | Niagara Falls, Ontario, Canada |
| 08524 | Deutsch Fastener Corp. | Los Angeles, Calif. |
| 08664 | Bristol Co., The | Waterbury, Conn. |
| 08717 | Sloan Company | Sun Valley, Calif. |
| 08718 | ITT Cannon Electric Inc., Phoenix Div. | Phoenix, Arizona |
| 08727 | National Radio Lab. Inc. | Paramus, N.J. |
| 08792 | CBS Electronics Semiconductor Operations, Div of C.B.S. Inc. | Lowell, Mass. |
| 08984 | Mel-Rain | Indianapolis, Ind. |
| 09026 | Babcock Relays Div. | Costa Mesa, Calif. |
| 09134 | Texas Capacitor Co. | Houston, Texas |
| 09145 | Tech. Ind. Inc. Atohm Elect. | Burbank, Calif. |
| 09250 | Electro Assemblies, Inc. | Chicago, Ill. |
| 09569 | Mallory Battery Co. of Canada, Ltd. | Toronto, Ontario, Canada |
| 10214 | General Transistor Western Corp. | Los Angeles, Calif. |
| 10411 | Ti-Tal, Inc. | Berkeley, Calif. |
| 10646 | Carborundum Co. | Niagara Falls, N.Y. |
| 11236 | CTS of Berne, Inc. | Berne, Ind. |
| 11237 | Chicago Telephone of California, Inc. | So. Pasadena, Calif. |
| 11242 | Bay State Electronics Corp. | Waltham, Mass. |
| 11312 | Teledyne Inc., Microwave Div. | Palo Alto, Calif. |
| 11314 | National Seal | Downey, Calif. |
| 11534 | Duncan Electronics Inc. | Costa Mesa, Calif. |
| 11711 | General Instrument Corp., Semiconductor Div., Products Group | Newark, N.J. |
| 11717 | Imperial Electronic, Inc. | Buena Park, Calif. |
| 11870 | Melabs, Inc. | Palo Alto, Calif. |
| 12136 | Philadelphia Handle Co. | Camden, N.J. |
| 12361 | Grove Mfg. Co., Inc. | Shady Grove, Pa. |
| 12574 | Gulton Ind. Inc. Data System Div. | Albuquerque, N.M. |
| 12697 | Clarostat Mfg. Co. | Dover, N.H. |
| 12728 | Elmar Filter Corp. | W. Haven, Conn. |
| 12859 | Nippon Electric Co., Ltd. | Tokyo, Japan |
| 12881 | Metex Electronics Corp. | Clark, N.J. |
| 12930 | Delta Semiconductor Inc. | Newport Beach, Calif. |
| 12954 | Dickson Electronics Corp. | Scottsdale, Arizona |
| 13103 | Thermolloy | Dallas, Texas |
| 13396 | Telefunken (GmbH) | Hanover, Germany |
| 13835 | Midland-Wright Div. of Pacific Industries, Inc. | Kansas City, Kansas |
| 14099 | Sem-Tech | Newbury Park, Calif. |
| 14193 | Calif. Resistor Corp. | Santa Monica, Calif. |
| 14298 | American Components, Inc. | Conshohocken, Pa. |
| 14433 | ITT Semiconductor, A Div. of Int. Telephone & Telegraph Corp. | West Palm Beach, Fla. |
| 14493 | Hewlett-Packard Company | Loveland, Colo. |
| 14655 | Cornell Dublier Electric Corp. | Newark, N.J. |
| 14674 | Corning Glass Works | Corning, N.Y. |
| 14752 | Electro Cube Inc. | San Gabriel, Calif. |
| 14960 | Williams Mfg. Co. | San Jose, Calif. |
| 15203 | Webster Electronics Co. | New York, N.Y. |
| 15287 | Scionics Corp. | Northridge, Calif. |
| 15291 | Adjustable Bushing Co. | N. Hollywood, Calif. |
| 15558 | Micron Electronics | Garden City, Long Island, N.Y. |
| 15566 | Amprobe Inst. Corp. | Lynbrook, N.Y. |
| 15631 | Cabletronics | Costa Mesa, Calif. |
| 15772 | Twentieth Century Coil Spring Co. | Santa Clara, Calif. |
| 15801 | Fenwal Elect. Inc. | Framingham, Mass. |
| 15818 | Amelco Inc. | Mt. View, Calif. |
| 16037 | Spruce Pine Mica Co. | Spruce Pine, N.C. |
| 16179 | Omni-Spectra Inc. | Detroit, Ill. |
| 16352 | Computer Diode Corp. | Lodi, N.J. |
| 16688 | Ideal Prec. Meter Co., Inc. De Jur Meter Div. | Brooklyn, N.Y. |
| 16758 | Delco Radio Div. of G.M. Corp. | Kokoma, Ind. |
| 17109 | Thermonetics Inc. | Canoga Park, Calif. |
| 17474 | Tranex Company | Mountain View, Calif. |
| 17675 | Hamlin Metal Products Corp. | Akron, Ohio |
| 17745 | Angstrohm Prec. Inc. | No. Hollywood, Calif. |
| 17870 | McGraw-Edison Co. | Manchester, N.H. |
| 18042 | Power Design Pacific Inc. | Palo Alto, Calif. |
| 18083 | Clevite Corp., Semiconductor Div. | Palo Alto, Calif. |
| 18324 | Signetics Corp. | Sunnyvale, Calif. |
| 18476 | Ty-Car Mfg. Co., Inc. | Holliston, Mass. |
| 18486 | TRW Elect. Comp. Div. | Des Plaines, Ill. |
| 18583 | Curtis Instrument, Inc. | Mt. Kisco, N.Y. |
| 18612 | Vishay Intertechnology, Inc. | Malvern, Pa. |
| 18873 | E.I. DuPont and Co., Inc. | Wilmington, Del. |
| 18911 | Durant Mfg. Co. | Milwaukee, Wis. |
| 19315 | The Bendix Corp., Navigation & Control Div. | Teterboro, N.J. |



From: FSC. Handbook Supplements
H4-1 Dated AUGUST 1966
H4-2 Dated NOV. 1962

# CODE LIST OF MANUFACTURERS (Cont'd)

| Code No. | Manufacturer | Address |
|---|---|---|
| 19500 | Thomas A. Edison Industries, Div. of McGraw-Edison Co. | West Orange, N.J. |
| 19589 | Concoa | Baldwin Park, Calif. |
| 19644 | LRC Electronics | Horseheads, N.Y. |
| 19701 | Electra Mfg. Co. | Independence, Kansas |
| 20183 | General Atronics Corp. | Philadelphia, Pa. |
| 21226 | Executone, Inc. | Long Island City, N.Y. |
| 21335 | Fafnir Bearing Co., The | New Britain, Conn. |
| 21520 | Fansteel Metallurgical Corp. | N. Chicago, Ill. |
| 23783 | British Radio Electronics Ltd. | Washington, D.C. |
| 24455 | G.E. Lamp Division | Nela Park, Cleveland, Ohio |
| 24655 | General Radio Co. | West Concord, Mass. |
| 24681 | Memcor Inc., Comp. Div. | Huntington, Ind. |
| 26365 | Gries Reproducer Corp. | New Rochelle, N.Y. |
| 26462 | Grobet File Co. of America, Inc. | Carlstadt, N.J. |
| 26851 | Compac/Hollister Co. | Hollister, Calif. |
| 26992 | Hamilton Watch Co. | Lancaster, Pa. |
| 28480 | Hewlett-Packard Co. | Palo Alto, Calif. |
| 28520 | Heyman Mfg. Co. | Kenilworth, N.J. |
| 30817 | Instrument Specialties Co., Inc. | Little Falls, N.J. |
| 33173 | G.E. Receiving Tube Dept. | Owensboro, Ky. |
| 35434 | Lectrohm Inc. | Chicago, Ill. |
| 36196 | Stanwyck Coil Products Ltd. | Hawkesbury, Ontario, Canada |
| 36287 | Cunningham, W.H. & Hill, Ltd. | Toronto Ontario, Canada |
| 37942 | P.R. Mallory & Co. Inc. | Indianapolis, Ind. |
| 39543 | Mechanical Industries Prod. Co. | Akron, Ohio |
| 40920 | Miniature Precision Bearings, Inc. | Keene, N.H. |
| 42190 | Muter Co. | Chicago, Ill. |
| 43990 | C.A. Norgren Co. | Englewood, Colo. |
| 44655 | Ohmite Mfg. Co. | Skokie, Ill. |
| 46384 | Penn Eng. & Mfg. Corp. | Doylestown, Pa. |
| 47904 | Polaroid Corp. | Cambridge, Mass. |
| 48620 | Precision Thermometer & Inst. Co. | Southampton, Pa. |
| 49956 | Microwave & Power Tube Div. | Waltham, Mass. |
| 52090 | Rowan Controller Co. | Westminster, Md. |
| 52983 | Sanborn Company | Waltham, Mass. |
| 54294 | Shallcross Mfg. Co. | Selma, N.C. |
| 55026 | Simpson Electric Co. | Chicago, Ill. |
| 55933 | Sonotone Corp. | Elmsford, N.Y. |
| 55938 | Raytheon Co. Commercial Apparatus & Systems Div. | So. Norwalk, Conn. |
| 56137 | Spaulding Fibre Co., Inc. | Tonawanda, N.Y. |
| 56289 | Sprague Electric Co. | North Adams, Mass. |
| 59446 | Telex Corp. | Tulsa, Okla. |
| 59730 | Thomas & Betts Co. | Elizabeth, N.J. |
| 60741 | Triplett Electrical Inst. Co. | Bluffton, Ohio |
| 61775 | Union Switch and Signal, Div. of Westinghouse Air Brake Co. | Pittsburgh, Pa. |
| 62119 | Universal Electric Co. | Owosso, Mich. |
| 63743 | Ward-Leonard Electric Co. | Mt. Vernon, N.Y. |
| 64959 | Western Electric Co., Inc. | New York, N.Y. |
| 65092 | Weston Inst. Inc. Weston-Newark | Newark, N.J. |
| 66295 | Wittek Mfg. Co. | Chicago, Ill. |
| 66346 | Minnesota Mining & Mfg. Co. Revere Mincom Div. | St. Paul, Minn. |
| 70276 | Allen Mfg. Co. | Hartford, Conn. |
| 70309 | Allied Control | New York, N.Y. |
| 70318 | Allmetal Screw Product Co., Inc. | Garden City, N.Y. |
| 70417 | Amplex, Div. of Chrysler Corp. | Detroit, Mich. |
| 70485 | Atlantic India Rubber Works, Inc. | Chicago, Ill. |
| 70563 | Amperite Co., Inc. | Union City, N.J. |
| 70674 | ADC Products Inc. | Minneapolis, Minn. |
| 70903 | Belden Mfg. Co. | Chicago, Ill. |

| Code No. | Manufacturer | Address |
|---|---|---|
| 70998 | Bird Electronic Corp. | Cleveland, Ohio |
| 71002 | Birnbach Radio Co. | New York, N.Y. |
| 71034 | Bliley Electric Co., Inc. | Erie, Pa. |
| 71041 | Boston Gear Works Div. of Murray Co. of Texas | Quincy, Mass. |
| 71218 | Bud Radio, Inc. | Willoughby, Ohio |
| 71279 | Cambridge Thermionics Corp. | Cambridge, Mass. |
| 71286 | Camloc Fastener Corp. | Paramus, N.J. |
| 71313 | Cardwell Condenser Corp. | Lindenhurst L.I., N.Y. |
| 71400 | Bussmann Mfg. Div. of McGraw-Edison Co. | St. Louis, Mo. |
| 71436 | Chicago Condenser Corp. | Chicago, Ill. |
| 71447 | Calif. Spring Co., Inc. | Pico-Rivera, Calif. |
| 71450 | CTS Corp. | Elkhart, Ind. |
| 71468 | ITT Cannon Electric Inc. | Los Angeles, Calif. |
| 71471 | Cinema, Div. Aerovox Corp. | Burbank, Calif. |
| 71482 | C.P. Clare & Co. | Chicago, Ill. |
| 71590 | Centralab Div. of Globe Union Inc. | Milwaukee, Wis. |
| 71616 | Commercial Plastics Co. | Chicago, Ill. |
| 71700 | Cornish Wire Co., The | New York, N.Y. |
| 71707 | Coto Coil Co., Inc. | Providence, R.I. |
| 71744 | Chicago Miniature Lamp Works | Chicago, Ill. |
| 71785 | Cinch Mfg. Co., Howard B. Jones Div. | Chicago, Ill. |
| 71984 | Dow Corning Corp. | Midland, Mich. |
| 72136 | Electro Motive Mfg. Co., Inc. | Willimantic, Conn. |
| 72619 | Dialight Corp. | Brooklyn, N.Y. |
| 72656 | Indiana General Corp., Electronics Div. | Keasby, N.J. |
| 72699 | General Instrument Corp., Cap. Div. | Newark, N.J. |
| 72765 | Drake Mfg. Co. | Harwood Heights, Ill. |
| 72825 | Hugh H. Eby Inc. | Philadelphia, Pa. |
| 72928 | Gudeman Co. | Chicago, Ill. |
| 72962 | Elastic Stop Nut Corp. | Union, N.J. |
| 72964 | Robert M. Hadley Co. | Los Angeles, Calif. |
| 72982 | Erie Technological Products, Inc. | Erie, Pa. |
| 73061 | Hansen Mfg. Co., Inc. | Princeton, Ind. |
| 73076 | H.M. Harper Co. | Chicago, Ill. |
| 73138 | Helipot Div. of Beckman Inst., Inc. | Fullerton, Calif. |
| 73293 | Hughes Products Division of Hughes Aircraft Co. | Newport Beach, Calif. |
| 73445 | Amperex Elect Co. | Hicksville, L.I., N.Y. |
| 73506 | Bradley Semiconductor Corp. | New Haven, Conn. |
| 73559 | Carling Electric, Inc. | Hartford, Conn. |
| 73586 | Circle F Mfg. Co. | Trenton, N.J. |
| 73682 | George K. Garrett Co., Div. MSL Industries Inc. | Philadelphia, Pa. |
| 73734 | Federal Screw Products Inc. | Chicago, Ill. |
| 73743 | Fischer Special Mfg. Co. | Cincinnati, Ohio |
| 73793 | General Industries Co., The | Elyria, Ohio |
| 73846 | Goshen Stamping & Tool Co. | Goshen, Ind. |
| 73899 | JFD Electronics Corp. | Brooklyn, N.Y. |
| 73905 | Jennings Radio Mfg. Corp. | San Jose, Calif. |
| 73957 | Groov-Pin Corp. | Ridgefield, N.J. |
| 74276 | Signalite Inc. | Neptune, N.J. |
| 74455 | J.H. Winns, and Sons | Winchester, Mass. |
| 74861 | Industrial Condenser Corp. | Chicago, Ill. |
| 74868 | R.F. Products Division of Amphenol-Borg Electronics Corp. | Danbury, Conn. |
| 74970 | E.F. Johnson Co. | Waseca, Minn. |
| 75042 | International Resistance Co. | Philadelphia, Pa. |
| 75263 | Keystone Carbon Co., Inc. | St. Marys, Pa. |
| 75378 | CTS Knights Inc. | Sandwich, Ill. |
| 75382 | Kulka Electric Corporation | Mt. Vernon, N.Y. |
| 75818 | Lenz Electric Mfg. Co. | Chicago, Ill. |
| 75915 | Littlefuse, Inc. | Des Plaines, Ill. |
| 76005 | Lord Mfg. Co. | Erie, Pa. |

| Code No. | Manufacturer | Address |
|---|---|---|
| 76210 | C.W. Marwedel | San Francisco, Calif. |
| 76433 | General Instrument Corp., Micamold Division | Newark, N.J. |
| 76487 | James Millen Mfg. Co., Inc. | Malden, Mass. |
| 76493 | J.W. Miller Co. | Los Angeles, Calif. |
| 76530 | Cinch-Monadnock, Div. of United Carr Fastener Corp. | San Leandro, Calif. |
| 76545 | Mueller Electric Co. | Cleveland, Ohio |
| 76703 | National Union | Newark, N.J. |
| 76854 | Oak Manufacturing Co. | Crystal Lake, Ill. |
| 77068 | The Bendix Corp., Electrodynamics Div. | N. Hollywood, Calif. |
| 77075 | Pacific Metals Co. | San Francisco, Calif. |
| 77221 | Phanostran Instrument and Electronic Co. | South Pasadena, Calif. |
| 77252 | Philadelphia Steel and Wire Corp. | Philadelphia, Pa. |
| 77342 | American Machine & Foundry Co. Potter & Brumfield Div. | Princeton, Ind. |
| 77630 | TRW Electronic Components Div. | Camden, N.J. |
| 77638 | General Instrument Corp., Rectifier Div. | Brooklyn, N.Y. |
| 77764 | Resistance Products Co. | Harrisburg, Pa. |
| 77969 | Rubbercraft Corp. of Calif. | Torrance, Calif. |
| 78189 | Shakeproof Division of Illinois Tool Works | Elgin, Ill. |
| 78277 | Sigma | So. Braintree, Mass. |
| 78283 | Signal Indicator Corp. | New York, N.Y. |
| 78290 | Struthers-Dunn Inc. | Pitman, N.J. |
| 78452 | Thompson-Bremer & Co. | Chicago, Ill. |
| 78471 | Tilley Mfg. Co. | San Francisco, Calif. |
| 78488 | Stackpole Carbon Co. | St. Marys, Pa. |
| 78493 | Standard Thomson Corp. | Waltham, Mass. |
| 78553 | Tinnerman Products, Inc. | Cleveland, Ohio |
| 78790 | Transformer Engineers | San Gabriel, Calif. |
| 78947 | Ucinite Co. | Newtonville, Mass. |
| 79136 | Waldes Kohinoor Inc. | Long Island City, N.Y. |
| 79142 | Veeder Root, Inc. | Hartford, Conn. |
| 79251 | Wenco Mfg. Co. | Chicago, Ill. |
| 79727 | Continental-Wirt Electronics Corp. | Philadelphia, Pa. |
| 79963 | Zierick Mfg. Corp. | New Rochelle, N.Y. |
| 80031 | Mepco Division of Sessions Clock Co. | Morristown, N.J. |
| 80120 | Schnitzer Alloy Products Co. | Elizabeth, N.J. |
| 80131 | Electronic Industries Association. Any brand Tube meeting EIA Standards-Washington, DC. | |
| 80207 | Unimax Switch, Div. Maxon Electronics Corp. | Wallingford, Conn. |
| 80223 | United Transformer Corp. | New York, N.Y. |
| 80248 | Oxford Electric Corp. | Chicago, Ill. |
| 80294 | Bourns Inc. | Riverside, Calif. |
| 80411 | Acro Div. of Robertshaw Controls Co. | Columbus, Ohio |
| 80486 | All Star Products Inc. | Defiance, Ohio |
| 80509 | Avery Label Co. | Monrovia, Calif. |
| 80583 | Hammarlund Co., Inc. | New York, N.Y. |
| 80640 | Stevens, Arnold, Co., Inc. | Boston, Mass. |
| 80813 | Dimco Gray Co. | Dayton, Ohio |
| 81030 | International Instruments Inc. | Orange, Conn. |
| 81073 | Grayhill Co. | LaGrange, Ill. |
| 81095 | Triad Transformer Corp. | Venice, Calif. |
| 81312 | Winchester Elec. Div. Litton Ind., Inc. | Oakville, Conn. |
| 81349 | Military Specification | . . . . . . |
| 81483 | International Rectifier Corp. | El Segundo, Calif. |
| 81541 | Airpax Electronics, Inc. | Cambridge, Maryland |
| 81860 | Barry Controls, Div. Barry Wright Corp. | Watertown, Mass. |
| 82042 | Carter Precision Electric Co. | Skokie, Ill. |

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## CODE LIST OF MANUFACTURERS (Cont'd)

| Code No. | Manufacturer | Address |
|---|---|---|
| 82047 | Sperti Faraday Inc., Copper Hewitt Electric Div. | Hoboken, N.J. |
| 82142 | Jeffers Electronics Division of Speer Carbon Co. | Du Bois, Pa. |
| 82170 | Fairchild Camera & Inst. Corp. Space & Defense System Div. | Paramus, N.J. |
| 82209 | Maguire Industries, Inc. | Greenwich, Conn. |
| 82219 | Sylvania Electric Prod. Inc. Electronic Tube Division | Emporium, Pa. |
| 82376 | Astron Corp. | East Newark, Harrison, N.J. |
| 82389 | Switchcraft, Inc. | Chicago, Ill. |
| 82647 | Metals & Controls Inc. Spencer Products | Attleboro, Mass. |
| 82768 | Phillips-Advance Control Co. | Joliet, Ill. |
| 82866 | Research Products Corp. | Madison, Wis. |
| 82877 | Rotron Mfg. Co., Inc. | Woodstock, N.Y. |
| 82893 | Vector Electronic Co. | Glendale, Calif. |
| 83058 | Carr Fastener Co. | Cambridge, Mass. |
| 83086 | New Hampshire Ball Bearing, Inc. | Peterborough, N.H. |
| 83125 | General Instrument Corp., Capacitor Div. | Darlington, S.C. |
| 83148 | ITT Wire and Cable Div. | Los Angeles, Calif. |
| 83186 | Victory Eng. Corp. | Springfield, N.J. |
| 83298 | Bendix Corp., Red Bank Div. | Red Bank, N.J. |
| 83315 | Hubbell Corp. | Mundelein, Ill. |
| 83324 | Rosan Inc. | Newport Beach, Calif. |
| 83330 | Smith, Herman H., Inc. | Brooklyn, N.Y. |
| 83332 | Tech Labs | Palisade's Park, N.J. |
| 83385 | Central Screw Co. | Chicago, Ill. |
| 83501 | Gavitt Wire and Cable Co. Div. of Amerace Corp. | Brookfield, Mass. |
| 83594 | Burroughs Corp. Electronic Tube Div. | Plainfield, N.J. |
| 83740 | Union Carbide Corp. Consumer Prod. Div. | New York, N.Y. |
| 83777 | Model Eng. and Mfg., Inc. | Huntington, Ind. |
| 83821 | Loyd Scruggs Co. | Festus, Mo. |
| 83942 | Aeronautical Inst. & Radio Co. | Lodi, N.J. |
| 84171 | Arco Electronics Inc. | Great Neck, N.Y. |
| 84396 | A.J. Glesener Co., Inc. | San Francisco, Calif. |
| 84411 | TRW Capacitor Div. | Ogallala, Neb. |
| 84970 | Sarkes Tarzian, Inc. | Bloomington, Ind. |
| 85454 | Boonton Molding Company | Boonton, N.J. |
| 85471 | A.B. Boyd Co. | San Francisco, Calif. |
| 85474 | R.M. Bracamonte & Co. | San Francisco, Calif. |
| 85660 | Koiled Kords, Inc. | Hamden, Conn. |
| 85911 | Seamless Rubber Co. | Chicago, Ill. |
| 86197 | Clifton Precision Products Co., Inc. | Clifton Heights, Pa. |
| 86579 | Precision Rubber Products Corp. | Dayton, Ohio |
| 86684 | Radio Corp. of America, Electronic Comp. & Devices Div. | Harrison, N.J. |
| 87034 | Marco Industries | Anaheim, Calif. |
| 87216 | Philco Corporation (Lansdale Division) | Lansdale, Pa. |
| 87473 | Western Fibrous Glass Products Co. | San Francisco, Calif. |
| 87664 | Van Waters & Rogers Inc. | San Francisco, Calif. |
| 87930 | Tower Mfg. Corp. | Providence, R.I. |
| 88140 | Cutler-Hammer, Inc. | Lincoln, Ill. |
| 88220 | Gould-National Batteries, Inc. | St. Paul, Minn. |
| 88698 | General Mills, Inc. | Buffalo, N.Y. |
| 89231 | Graybar Electric Co. | Oakland, Calif. |
| 89473 | G.E. Distributing Corp. | Schenectady, N.Y. |
| 89665 | United Transformer Co. | Chicago, Ill. |
| 90030 | United Shoe Machinery Corp. | Beverly, Mass. |
| 90179 | US Rubber Co., Consumer Ind. & Plastics Prod. Div. | Passaic, N.J. |
| 90970 | Bearing Engineering Co. | San Francisco, Calif. |
| 91146 | ITT Cannon Elect, Inc., Salem Div. | Salem, Mass. |
| 91260 | Connor Spring Mfg. Co. | San Francisco, Calif. |
| 91345 | Miller Dial & Nameplate Co. | El Monte, Calif. |
| 91418 | Radio Materials Co. | Chicago, Ill. |
| 91506 | Augat Inc. | Attleboro, Mass. |
| 91637 | Dale Electronics, Inc. | Columbus, Nebr. |
| 91662 | Elco Corp. | Willow Grove, Pa. |
| 91737 | Gremar Mfg. Co., Inc. | Wakefield, Mass. |
| 91827 | K F Development Co. | Redwood City, Calif. |
| 91886 | Malco Mfg. Co., Inc. | Chicago, Ill. |
| 91929 | Honeywell Inc., Micro Switch Div. | Freeport, Ill. |
| 91961 | Nahm-Bros. Spring Co. | Oakland, Calif. |
| 92180 | Tru-Connector Corp. | Peabody, Mass. |
| 92367 | Elgeet Optical Co. Inc. | Rochester, N.Y. |
| 92607 | Tensolite Insulated Wire Co., Inc. | Tarrytown, N.Y. |
| 92702 | IMC Magnetics Corp. | Wesbury Long Island, N.Y. |
| 92966 | Hudson Lamp Co. | Kearney, N.J. |
| 93332 | Sylvania Electric Prod. Inc. Semiconductor Div. | Woburn, Mass. |
| 93369 | Robbins & Myers Inc. | Palisades Park, N.J. |
| 93410 | Stevens Mfg. Co., Inc. | Mansfield, Ohio |
| 93632 | Waters Mfg. Co. | Culver City, Calif. |
| 93929 | G.V. Controls | Livingston, N.J. |
| 94137 | General Cable Corp. | Bayonne, N.J. |
| 94144 | Raytheon Co., Comp. Div., Ind. Comp. Operations | Quincy, Mass. |
| 94148 | Scientific Electronics Products, Inc. | Loveland, Colo. |
| 94154 | Wagner Elect. Corp., Tung-Sol Div. | Newark, N.J. |
| 94197 | Curtiss-Wright Corp. Electronics Div. | East Paterson, N.J. |
| 94222 | South Chester Corp. | Chester, Pa. |
| 94330 | Wire Cloth Products, Inc. | Bellwood, Ill. |
| 94375 | Automatic Metal Products Co. | Brooklyn, N.Y. |
| 94682 | Worcester Pressed Aluminum Corp. | Worcester, Mass. |
| 94696 | Magnecraft Electric Co. | Chicago, Ill. |
| 95023 | George A. Philbrick Researchers, Inc. | Boston, Mass. |
| 95236 | Allies Products Corp., | Dania, Fla. |
| 95238 | Continental Connector Corp. | Woodside, N.Y. |
| 95263 | Leecraft Mfg. Co., Inc. | Long Island, N.Y. |
| 95265 | National Coil Co. | Sheridan, Wyo. |
| 95275 | Vitramon, Inc. | Bridgeport, Conn. |
| 95348 | Gordos Corp. | Bloomfield, N.J. |
| 95354 | Methode Mfg. Co. | Rolling Meadows, Ill. |
| 95566 | Arnold Engineering Co. | Marengo, Ill. |
| 95712 | Dage Electric Co., Inc. | Franklin, Ind. |
| 95984 | Siemon Mfg. Co. | Wayne, Ill. |
| 95987 | Weckesser Co. | Chicago, Ill. |
| 96067 | Huggins Laboratories | Sunnyvale, Calif. |
| 96095 | Hi-Q Div. of Aerovox Corp. | Olean, N.Y. |
| 96256 | Thordarson-Meissner Inc. | Mt. Carmel, Ill. |
| 96296 | Solar Manufacturing Co. | Los Angeles, Calif. |
| 96330 | Carlton Screw Co. | Chicago, Ill. |
| 96341 | Microwave Associates, Inc. | Burlington, Mass. |
| 96501 | Excel Transformer Co. | Oakland, Calif. |
| 97464 | Industrial Retaining Ring Co. | Irvington, N.J. |
| 97539 | Automatic & Precision Mfg. | Englewood, N.J. |
| 97979 | Reon Resistor Corp. | Yonkers, N.Y. |
| 97983 | Litton System Inc., Adler-Westrex Commun. Div. | New Rochelle, N.Y. |
| 98141 | R-Troncis, Inc. | Jamaica, N.Y. |
| 98159 | Rubber Teck, Inc. | Gardena, Calif. |
| 98220 | Hewlett-Packard Co., Moseley Div. | Pasadena, Calif. |
| 98278 | Microdot, Inc. | So. Pasadena, Calif. |
| 98291 | Sealectro Corp. | Mamaroneck, N.Y. |
| 98376 | Zero Mfg. Co. | Burbank, Calif. |
| 98731 | General Mills Inc., Electronics Div. | Minneapolis, Minn. |
| 98734 | Paeco Div. of Hewlett-Packard Co. | Palo Alto, Calif. |
| 98821 | North Hills Electronics, Inc. | Glen Cove, N.Y. |
| 98978 | International Electronic Research Corp. | Burbank, Calif. |
| 99109 | Columbia Technical Corp. | New York, N.Y. |
| 99313 | Varian Associates | Palo Alto, Calif. |
| 99378 | Atlee Corp. | Winchester, Mass. |
| 99515 | Marshall Ind., Capacitor Div. | Monrovia, Calif. |
| 99707 | Control Switch Division, Controls Co. of America | El Segundo, Calif. |
| 99800 | Delevan Electronics Corp. | East Aurora, N.Y. |
| 99848 | Wilco Corporation | Indianapolis, Ind. |
| 99934 | Renbrandt, Inc. | Boston, Mass. |
| 99942 | Hoffman Electronics Corp. Semiconductor Div. | El Monte, Calif. |
| 99957 | Technology Instrument Corp. of Calif. | Newbury Park, Calif. |

THE FOLLOWING HP VENDORS HAVE NO NUMBER ASSIGNED IN THE LATEST SUPPLEMENT TO THE FEDERAL SUPPLY CODE FOR MANUFACTURERS HANDBOOK.

| Code No. | Manufacturer | Address |
|---|---|---|
| 0000F | Malco Tool and Die | Los Angeles, Calif. |
| 0000Z | Willow Leather Products Corp. | Newark, N.J. |
| 000AB | ETA | England |
| 000BB | Precision Instrument Components Co. | Van Nuys, Calif. |
| 000CS | Hewlett-Packard Co., Colorado Springs | Colorado Springs, Colorado |
| 000MM | Rubber Eng. & Development | Hayward, Calif. |
| 000NN | A "N" D Mfg. Co. | San Jose, Calif. |
| 000QQ | Cooltron | Oakland, Calif. |
| 000WW | California Eastern Lab. | Burlington, Calif. |
| 000YY | S.K. Smith Co. | Los Angeles, Calif. |

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# ELECTRONIC INSTRUMENTATION SALES AND SERVICE
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Lavalle 1171 - 3°
**Buenos Aires**

Lutz, Ferrando y Cia. S. A.
Florida 240 (R.5)
**Buenos Aires**
Tel: 46-7241, 46-1635
Cable: OPTICA Buenos Aires

**BRAZIL**
Hewlett-Packard Do Brasil
I.e.C. Ltda.
Rua Cel. Oscar Porto, 691
**Sao Paulo** - 8, SP
Tel: 71-1503
Cable: HEWPAK Sao Paulo

Hewlett-Packard Do Brasil
I.e.C. Ltda.
Avenida Franklin Roosevelt 84-grupo 203
**Rio de Janeiro,** ZC-39, GB
Tel: 32-9733
Cable: HEWPAK Rio de Janeiro

**CHILE**
Hector Calcagni P.
Casilla 13942
Estado 215 - Oficina 1016
**Santiago**
Tel: 31-890, 490-505

**COLOMBIA**
Instrumentacion
Henrik A. Langebaek & Cia. Ltda.
Carrera 7 # 48-59
Apartado Aéreo 6287
**Bogota,** 1. D.E.
Tel: 45-78-06, 45-55-46
Cable: AARIS Bogota

**COSTA RICA**
Lic. Alfredo Gallegos Gurdián
Apartado 3243
**San José**
Tel: 21-86-13
Cable: GALGUR San José

**ECUADOR**
Laboratorios de Radio-Ingenieria
Calle Guayaquil 1246
Post Office Box 3199
**Quito**
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**EL SALVADOR**
Electrónica
Apartado Postal 1589
27 Avenida Norte 1133
**San Salvador**
Tel: 25 74 50
Cable: ELECTRONICA San Salvador

**GUATEMALA**
Olander Associates Latin America
Apartado 1226
7a. Calle, 0-22, Zona 1
**Guatemala City**
Tel: 22812
Cable: OLALA Guatemala City

**MEXICO**
Hewlett-Packard Mexicana, S.A. de C.V.
Apartado Postal 12-832
**Eugenia** 408, Dept. 1
Mexico 12, D.F.
Tel: 43-03-79, 36-08-78

**NICARAGUA**
Roberto Terán G.
Apartado Postal 689
Edificio Teran
**Managua**
Tel: 3451, 3452
Cable: ROTERAN Managua

**PANAMA**
Electronica Balboa, S.A.
P.O. Box 4929
Ave. Manuel Espinosa No. 13-50
Bldg. Alina
**Panama City**
Tel: 30833
Cable: ELECTRON Panama City

**PERU**
Fernando Ezeta B.
Avenida Petit Thouars 4719
Miraflores
Casilla 3061
**Lima**
Tel: 50346
Cable: FEPERU Lima

**PUERTO RICO**
San Juan Electronics, Inc.
P.O. Box 5167
Ponce de Leon 154
Pda. 3-Pta. de Tierra
**San Juan,** P.R. 00906
Tel: (174) 725-3342
Cable: SATRONICS San Juan

**URUGUAY**
Pablo Ferrando S.A.
Comercial e Industrial
Avenida Italia 2877
Casilla de Correo 370
**Montevideo**
Tel: 40-3102
Cable: RADIUM Montevideo

**VENEZUELA**
Hewlett-Packard De Venezuela C.A.
Edificio Arisán-Of. 4
Avda. Francisco de Miranda
Chacaito
**Caracas**
Tel: 71.88.05
Cable: HEWPACK Caracas
Mailing Address: Apartado del Este 10934 Caracas

**FOR AREAS NOT LISTED, CONTACT:**
Hewlett-Packard Inter-Americas
1501 Page Mill Road
**Palo Alto,** California 94304
Tel: (415) 326-7000
TWX: 910-373-1267
Telex: 034-8461
Cable: HEWPACK Palo Alto

## UNITED STATES

**ALABAMA**
P.O. Box 4207
2003 Byrd Spring Road S.W.
**Huntsville** 35802
Tel: (205) 881-4591
TWX: 810-726-2204

**ARIZONA**
3009 North Scottsdale Road
**Scottsdale** 85251
Tel: (602) 945-7601
TWX: 910-950-1282

5737 East Broadway
**Tuscon** 85716
Tel: (602) 298-2313
TWX: 910-952-1162

**CALIFORNIA**
3939 Lankershim Boulevard
**North Hollywood** 91604
Tel: (213) 877-1282
TWX: 910-499-2170

1101 Embarcadero Road
**Palo Alto** 94303
Tel: (415) 327-6500
TWX: 910-373-1280

2591 Carlsbad Avenue
**Sacramento** 95821
Tel: (916) 482-1463
TWX: 910-367-2092

1055 Shafter Street
**San Diego** 92106
Tel: (714) 223-8103
TWX: 910-335-2000

**COLORADO**
7965 East Prentice
**Englewood** 80110
Tel: (303) 771-3455
TWX: 910-935-0705

**CONNECTICUT**
508 Tolland Street
**East Hartford** 06108
Tel: (203) 289-9394
TWX: 710-425-3416

111 East Avenue
**Norwalk** 06851
Tel: (203) 853-1251
TWX: 710-468-3750

**DELAWARE**
3941 Kennett Pike
**Wilmington** 19807
Tel: (302) 655-6161
TWX: 510-666-2214

**FLORIDA**
P.O. Box 545
Suite 106
9999 N.E. 2nd Avenue
**Miami Shores** 33153
Tel: (305) 758-3626
TWX: 810-848-7262

P.O. Box 20007
Herndon Station 32814
621 Commonwealth Avenue
**Orlando**
Tel: (305) 841-3970
TWX: 810-850-0113

P.O. Box 8128
Madeira Beach 33708
410 150th Avenue
**St. Petersburg**
Tel: (813) 391-0211
TWX: 810-863-0366

**GEORGIA**
P.O. Box 28234
2340 Interstate Parkway
**Atlanta** 30328
Tel: (404) 436-6181
TWX: 810-766-4890

**ILLINOIS**
5500 Howard Street
**Skokie** 60076
Tel: (312) 677-0400
TWX: 910-223-3613

**INDIANA**
4002 Meadows Drive
**Indianapolis** 46205
Tel: (317) 546-4891
TWX: 810-341-3263

**LOUISIANA**
P.O. Box 856
1942 Williams Boulevard
**Kenner** 70062
Tel: (504) 721-6201
TWX: 810-955-5524

**MARYLAND**
6707 Whitestone Road
**Baltimore** 21207
Tel: (301) 944-5400
TWX: 710-862-0850

P.O. Box 727
Twinbrook Station 20851
12303 Twinbrook Parkway
**Rockville**
Tel: (301) 427-7560
TWX: 710-828-9684

**MASSACHUSETTS**
32 Hartwell Road
**Lexington** 02173
Tel: (617) 861-8960
TWX: 710-332-0382

**MICHIGAN**
24315 Northwestern Highway
**Southfield** 48075
Tel: (313) 353-9100
TWX: 810-232-1532

**MINNESOTA**
2459 University Avenue
**St. Paul** 55114
Tel: (612) 645-9461
TWX: 910-563-3734

**MISSOURI**
9208 Wyoming Place
**Kansas City** 64114
Tel: (816) 333-2445
TWX: 910-771-2087

2812 South Brentwood Blvd.
**St. Louis** 63144
Tel: (314) 644-0220
TWX: 910-760-1670

**NEW JERSEY**
W. 120 Century Road
**Paramus** 07652
Tel: (201) 265-5000
TWX: 710-990-4951

**NEW MEXICO**
P.O. Box 8366
Station C
6501 Lomas Boulevard N.E.
**Albuquerque** 87108
Tel: (505) 255-5586
TWX: 910-989-1665

156 Wyatt Drive
**Las Cruces** 88001
Tel: (505) 526-2485
TWX: 910-983-0550

**NEW YORK**
1702 Central Avenue
**Albany** 12205
Tel: (518) 869-8462
TWX: 710-441-8270

1219 Campville Road
**Endicott** 13764
Tel: (607) 754-0050
TWX: 510-252-0890

82 Washington Street
**Poughkeepsie** 12601
Tel: (914) 454-7330
TWX: 510-248-0012

39 Saginaw Drive
**Rochester** 14623
Tel: (716) 473-9500
TWX: 510-253-5981

1025 Northern Boulevard
**Roslyn, Long Island** 11576
Tel: (516) 869-8400
TWX: 510-223-0811

5858 East Molloy Road
**Syracuse** 13211
Tel: (315) 454-2486
TWX: 710-541-0482

**NORTH CAROLINA**
P.O. Box 5188
1923 North Main Street
**High Point** 27262
Tel: (919) 882-6873
TWX: 510-926-1516

**OHIO**
5579 Pearl Road
**Cleveland** 44129
Tel: (216) 884-9209
TWX: 810-421-8500

3460 South Dixie Drive
**Dayton** 45439
Tel: (513) 298-0351
TWX: 810-459-1925

**OKLAHOMA**
2919 United Founders Boulevard
**Oklahoma City** 73112
Tel: (405) 848-2801
TWX: 910-830-6862

**OREGON**
Westhills Mall, Suite 158
4475 S.W. Scholls Ferry Road
**Portland** 97225
Tel: (503) 292-9171
TWX: 910-464-6103

**PENNSYLVANIA**
2500 Moss Side Boulevard
**Monroeville** 15146
Tel: (412) 271-0724
TWX: 710-797-3650

144 Elizabeth Street
**West Conshohocken** 19428
Tel: (215) 248-1600, 828-6200
TWX: 510-660-8715

**TEXAS**
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3605 Inwood Road
**Dallas** 75209
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TWX: 910-861-4081

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4242 Richmond Avenue
**Houston** 77027
Tel: (713) 667-2407
TWX: 910-881-2645

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225 Billy Mitchell Road
**San Antonio** 78226
Tel: (512) 434-4171
TWX: 910-871-1170

**UTAH**
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# MANUAL BACKDATING CHANGES

MODEL 651B

TEST OSCILLATOR

Manual Serial Prefixed: 811-
-hp- Part No. 00651-90005

This manual backdating sheet makes this manual applicable to earlier instruments. Instrument-component values that differ from those in the manual, yet are not listed in the backdating sheet, should be replaced using the part number given in the manual.

| Instrument Serial Prefix | Make Manual Changes | Instrument Serial Prefix | Make Manual Changes |
|---|---|---|---|
| 647-02850 and below | #1 | | |
| 647-01100 and below | #1 and 2 | | |
| | | | |
| | | | |

CHANGE #1

Change S1C13* to S1C13, 2.0 pF, 0150-0031.
Delete S1C14*.
Change A2C21* to 10 pF, 0150-0055.
Change A2R16* to 280 Ω 1%, 0757-1091.
Change A2R24* to 1 kΩ 1/4 W 5%, 0683-1025.
Change A2Q1 to Transistor FET, 1855-0004.
Change A2Q2 to Transistor, 1854-0337. } See Note
Change A2Q3 to Transistor, 1853-0046. }

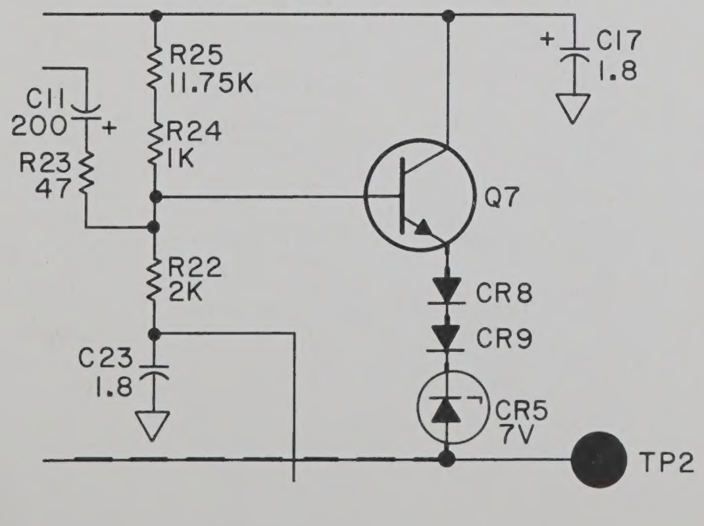
NOTE

If either A2Q2 or A2Q3 is changed to the new part number listed in Table 7-1 then all of the above components should also be changed to the new part numbers.

CHANGE #2

Delete A2C25*
Delete A2R46.
Change A2C11 to 200 μF, 0180-0060.
Change A2CR5 to Diode breakdown 7.87 V ±2%, 1902-0778.
Change A2Q7 to 2N3393, 1854-0218.
Change A2R25 to 11.75 kΩ, 0757-0757.

Change circuitry associated with A2Q7 as follows:



00651-90005

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